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ANGIOGRAPHIC DEMONSTRATION OF THE POSTERIOR COMMUNICATING AND POSTERIOR CEREBRAL ARTERIES

I. Normal angiography

by

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The incidence of angiographic demonstration of the posterior cerebral artery is stated by different authors to be between 20 and 30 % when carotid angiography is used. Anatomical studies have nevertheless shown that the posterior communicating artery is seldom absent; no investigator has mentioned this anomaly as having been observed in more than 5 % of cases. The reason why the posterior communicating artery is visible at carotid angiography in only about one-third of the examinations at which the necessary anatomical conditions for the free passage of the contrast medium are present has not apparently been previously investigated. It is therefore felt that a few observations throwing light on this discrepancy between the anatomical and angiographic findings may be of interest.

Material

Cerebral angiography is always performed on definite indications. Hence, no angiography has been performed on any subject entirely asymptomatic. The 'normal' material used in the present investigation

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consists of angiographies with no evidence of vascular lesions. It comprises 1 020 carotid angiographies carried out between 1953 and 1958. In addition to these 'conventional' carotid angiographies, a study was made of 232 'normal' carotid angiographies from the same period performed by the rapid serial method described by SJÖGREN & FREDZELL and GREITZ. Moreover, a series of 211 'normal' vertebral angiographies was also studied. All of these were carried out after percutaneous puncture of the vertebral artery (LINDGREN, SJÖGREN).

The statistical analyses were made by STAFFAN EKBLOM. Ordinary statistical methods were used, and the significance levels have been denoted as follows:

$0.05 > p > 0.01$	almost significant
$0.01 > p > 0.001$	significant
$0.001 > p$	highly significant

(By p is meant the probability that a difference between two values is due to chance.)

Conventional carotid angiographies

In the total material of 1 020 'conventional' carotid angiographies filling of the posterior cerebral artery was noted 354 times (34.7 ± 1.5 %). This is the highest incidence I have been able to find in the literature. In exceptional cases, retrograde filling of the basilar artery may be observed. This feature was noted in 11 of our angiographies (1.1 ± 0.3 %). KRAYENBÜHL & YAŞARGIL reported an incidence of 0.4 % for this finding. In addition to angiographies showing filling of the posterior cerebral artery, cases are occasionally encountered where the posterior communicating artery alone is demonstrated while the posterior cerebral artery is not visible. In the present material, 55 (5.4 ± 0.7 %) such cases were observed.

Of these 1 020 angiographies, 537 were performed in men and 483 in women. Comparing the incidence of filling of the posterior cerebral artery for the two sexes we obtained the figures: 189 out of 537 men (35.2 ± 2.1 %) and 165 out of 483 women (34.2 ± 2.2 %). The difference is not significant. No sex differences were found among the cases where the posterior communicating artery alone was visible.

The effect of age on the filling of the posterior cerebral artery may be seen from the diagram inserted here. In this the patients have been divided into 10-year groups. It will be noted that the posterior cerebral artery was visible less often in the youngest groups and most frequently in middle-aged patients, while the incidence dropped again slightly in the higher age-groups. The observations in the children are surprising, seeing that

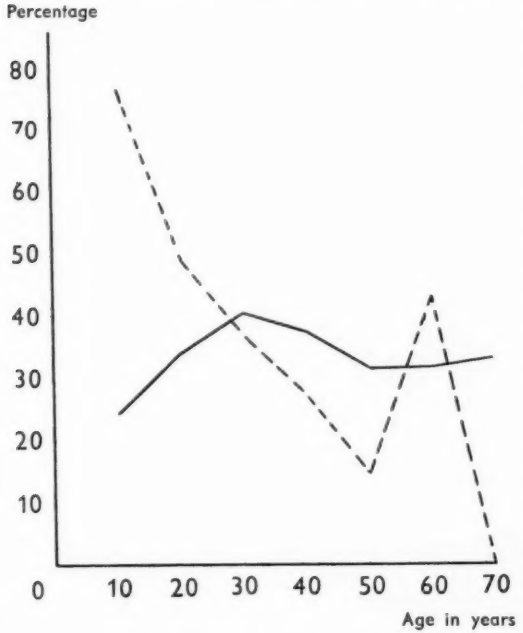

Diagram showing incidence of filling of the posterior cerebral artery (———) and of the posterior communicating artery alone (- - - - -) in patients of different ages. In the latter curve all values have been multiplied by 6.29 in order to bring the two curves to the same level.

De Vriese has demonstrated convincingly that the posterior communicating artery is widest in the foetus and the newborn infant, becoming noticeably narrower in adults. Our findings may possibly be connected with the higher pulse rate in children, which may easily cause the films to be taken a little late in the respective circulatory phases (cf. p. 18). Another possible explanation is that children are more difficult to puncture, and hence the risk of puncture complications is greater.

There was a striking age difference between cases where both the posterior communicating and posterior cerebral arteries were filled and those with filling of the posterior communicating artery alone. (See the aforementioned diagram.) The broken-line curve, which represents the latter category, shows in general a falling tendency with increasing age. As the curve is based on only a small number of cases the figures have also been assembled into two groups, namely, patients under and over 40. Filling of the posterior communicating artery alone was noted in 36 out of 512 patients under 40 (7.0 ± 1.1 %) and in 19 out of 508 over 40 (3.8 ± 0.9 %). The difference is almost significant. The corresponding figures for demonstration of both the posterior communicating and posterior cerebral arteries were 188 out of 512 under 40 (36.7 ± 2.1 %) and 166 out of 508 over 40 (32.7 ± 2.1 %). The difference here is not significant.

Of these angiographies, 481 were performed via the right carotid and 339 via the left carotid artery. The posterior cerebral artery was visible in 177 in each group. The corresponding percentage figures were 36.8

$\pm$ 2.2 % for the right carotid and 32.8 $\pm$ 2.0 % for the left carotid artery. The difference is not significant. Cases with filling of the posterior communicating artery alone were evenly distributed among right- and left-sided carotid angiographies.

Conventional carotid angiographies were performed on both sides in 146 patients. The figures in this part of the material are worthy of special consideration since the chances that these patients may represent a genuine normal series are greater than in the total material. In these 292 carotid angiographies, the posterior cerebral artery was demonstrated in 106 (36.3 $\pm$ 2.8 %). This figure is slightly higher than in the total material but the difference is not significant. In the individual cases, contrast filling of the posterior cerebral artery on both sides was noted in 23 (15.8 $\pm$ 5.0 %), on one side in 61 (41.8 $\pm$ 4.1 %), and on neither side in 62 cases (42.4 $\pm$ 4.1 %). A comparison of these results with corresponding calculations made by MONIZ shows that the posterior cerebral artery was demonstrated in a remarkably higher percentage in our material.

Site of puncture

Opinions differ as to which section of the vessel should be punctured for carotid angiography. Most neuroradiologists usually inject into the common carotid artery. MONIZ states very definitely that the puncture site selected should always allow injection into that vessel. In our department, we aim at selective injection, in other words, we endeavour to puncture the external carotid artery when information on that vessel is desired, and the internal carotid artery when its particular system is to be investigated. Only rarely do we attempt primarily to puncture the common carotid artery (in suspected thrombosis of the internal carotid, very small children).

It is, however, for several reasons not always possible to make the puncture in the vessel originally intended. My material is therefore mixed, consisting of 597 (58.5 %) internal carotid angiographies and 423 (41.5 %) common carotid angiographies. By common carotid angiography is in this connection meant all examinations where contrast medium was seen in the external carotid by the side of the internal carotid artery, irrespective of where the tip of the needle was situated. This definition is necessary, since, for many of the examinations, the exact position of the needle in the vascular system could not be ascertained. In an angiography showing filling of both internal and external carotid arteries the contrast material may have been injected into the internal carotid artery close to the bifurcation; the medium may then flow for a short distance in a retrograde direction and thereafter pass over into the external carotid artery.

The posterior cerebral artery was demonstrated in 248 out of 597 internal carotid angiographies (41.5 ± 2.0 %), and in 106 (25.1 ± 2.1 %) out of the 423 common carotid angiographies. The difference is highly significant. The incidence of filling of the posterior cerebral artery in the common carotid examinations is largely of the same order as figures previously reported. Of the 11 angiographies showing retrograde filling of the basilar artery, 10 (1.7 ± 0.5 %) had been performed via the internal carotid and one (0.24 ± 0.24 %) via the common carotid artery. The difference is almost significant.

To facilitate the evaluation of the common carotid angiographies I endeavoured in these to ascertain the position of the needle tip. This was successful in only 91 instances, in 56 of which the tip was so placed that injection into the common carotid artery could take place with an equally good chance of achieving filling of both external and internal carotid arteries. In the other 35, the needle either lay in the internal carotid artery, with backflow of contrast medium into the external carotid artery, or else it was situated in the common carotid artery but pointed towards the internal carotid so that the contrast density was higher in that vessel than in the external carotid artery. In the first group of 56 angiographies the posterior cerebral artery was filled in 14 (25.0 ± 5.8 %) and in the second group of 35 examinations in 9 (25.7 ± 7.4 %). Hence, no difference was established.

As regards cases where the posterior communicating artery alone was visible, the figures were 25 (4.2 ± 0.8 %) among the 597 internal carotid angiographies and 30 (7.1 ± 1.3 %) among the 423 common carotid examinations. The difference is almost significant.

In 21 instances injections were made into both the internal carotid and common carotid arteries on the same side. The two examinations were always performed in close succession. The posterior cerebral arteries were alike in 17 cases, being visible in 9 and not visible in 8. In the remaining 4, it was demonstrated in the internal carotid but not in the common carotid examination. Hence, not in a single case, when the posterior cerebral artery filled after injection into the common carotid artery, did it fail to fill after injection into the internal carotid artery.

Complications on carotid puncture

Although the number of perfect carotid punctures increases with increasing practice, no neuroradiologist can avoid occasional complications in the form of haematomas in the puncture area or extravascular injection of contrast medium. The topographic anatomy of the vessels varies to such a degree that even an examiner who consistently aims at

puncturing the internal carotid artery cannot avoid occasionally entering the external carotid artery first. These complications seem to have an effect on the filling of the posterior cerebral artery.

Haematomas are undoubtedly the most common complication of carotid angiography. In order to gain some idea of how these effusions influence the demonstration of the posterior cerebral artery I kept a record of the haematomas in 100 successive angiographies, in other words, an unselected series of normal and abnormal examinations. The incidence of haematoma was unusually high. These patients are not included in the other material. The posterior cerebral artery was demonstrated in 35 out of 100, *i. e.* the incidence was the same as in the normal material. Haematomas were recorded in 31 cases. Only haematomas noted before the contrast medium was injected were included. Filling of the posterior cerebral artery took place in 8 of these 31 cases (25.8 ± 7.9 %). Among the remaining 69 without haematomas the artery was demonstrated in 27 (39.1 ± 5.9 %). The material is small, however, and the difference is not significant.

Extravascular injection of contrast medium occurred in 101 of the 1 020 patients comprising the 'normal' material. The posterior cerebral artery was demonstrated in 25 of these 101 cases (24.8 ± 4.3 %). The corresponding figures for cases without extravascular injections were 329 among 919 examinations (35.8 ± 1.6%). The difference is almost significant. Dividing up the material into internal carotid and common carotid angiographies it was found that it was mainly the internal carotid examinations that were affected by the extravascular injections. The posterior cerebral artery was filled in 14 out of 55 (25.5 ± 5.9%) internal carotid angiographies and in 11 out of 46 (23.9 ± 6.3 %) common carotid examinations.

In 152 instances *contrast medium was injected into the external carotid artery* before the injection into the internal or common carotid artery. Double punctures in themselves involve an increased trauma, and the risk of haematoma is naturally greater when two vessels are to be punctured. The sequelae of these double punctures could not be thoroughly evaluated in any individual case, however, and hence the figures given here are only of limited value. The posterior cerebral artery was visible in 43 (28.3 ± 3.7 %) of these 152 examinations. Among the 862 cases in which the internal or common carotid artery was punctured without preliminary injection into the external carotid artery, the posterior cerebral artery was filled in 311 (36.1 ± 1.6 %). The tendency is the same as for the previously mentioned puncture complications, but the difference is not significant.

Blood pressure

No consistently planned *blood pressure measurements* were carried out in this material. To gain an idea of the significance of the blood pressure in the demonstration of the posterior cerebral artery, the pressure was measured in 100 cases immediately before angiography. No evidence suggesting that the blood pressure influences the filling of the posterior cerebral arteries was obtained. Dividing up the material according to the systolic blood pressure into cases with a pressure of up to 140 mm Hg and those with a pressure of 145 mm Hg and over, we have 50 examinations in each group. The posterior cerebral artery was demonstrated in 13 instances in the former group and in 20 in the latter. The difference is not significant.

General anaesthesia often reduces the blood pressure. In our clinic this form of anaesthesia is used as a routine in all children under 10, and sometimes in restless adults as well if technical difficulties are likely to arise. Of the 1 020 angiographies in the normal material, 87 (8.5 %) were carried out under anaesthesia, 52 of them in children and 35 in adults. General anaesthesia seems to have as little effect on the filling of the posterior cerebral artery as the blood pressure. Of these 87 angiographies the artery was visible in 27 (31.0 ± 5.0 %). The difference as against the total normal material is not significant.

A pressure difference favouring the carotid artery in relation to the vertebral artery system may be achieved by reducing the blood pressure in the latter artery. The author has demonstrated that with manual compression of the vertebral artery it is possible to demonstrate the posterior cerebral artery in some of the cases in which carotid angiography without vertebral compression is unsuccessful.

Rate of injection

The injection speed was recorded in 63 instances. As injection cannulas with the same lumen were consistently used, the volume of the contrast medium injected per unit of time was in constant ratio to the injection rate. The contrast medium was injected within a period of less than 2 seconds in 34 instances while in 29 the injection time was longer. The posterior cerebral artery was filled in 18 cases when the more rapid injection was used and in 7 with the longer time. Hence it seems as though this artery may be demonstrated more often with a rapid injection speed than with a slow one. The difference is almost significant.

Blood pressure levels were recorded in connection with angiography in 25 of the 63 cases in which the injection rate was registered. Nothing was

Table 1

Conventional carotid angiographies. Width of the contrast-filled posterior communicating artery in internal carotid and common carotid angiographies

	Wide		Average		Narrow		Totals of contrast-filled post. comm. artery		Number of angiographies performed
	No.	%	No.	%	No.	%	No.	%	
Internal carotid angiography	99	16.5 ± 1.5	108	18.1 ± 1.6	66	11.1 ± 1.3	273	45.7 ± 2.0	597
Common carotid angiography	40	9.5 ± 1.4	58	13.7 ± 1.7	38	9.0 ± 1.4	136	32.2 ± 2.3	423
Totals	139	13.6 ± 1.1	166	16.3 ± 1.2	104	10.2 ± 0.9	409	40.1 ± 1.5	1 020

noted suggesting that low blood pressures and short injection times were in any way correlated. In all probability therefore, the blood pressure does not affect the injection speed to any degree but the material is too small to permit definite conclusions to be drawn.

Diameter of posterior communicating artery

The diameter of the posterior communicating artery varies within a wide range. PADGET reviewed over 1 000 cases in the anatomical literature and found that the posterior communicating artery was stated to be wide in 29 %, normal in 49 %, and narrow in 23 % of subjects displaying this vascular communication. These figures are of limited interest, however, since the borderline values for the three groups were not given, and also since there is no guarantee that different authors used an identical scale of evaluation.

The lumen of the posterior communicating artery was measured in the lateral view in the 354 cases where the posterior cerebral artery, and hence the posterior communicating artery also, were demonstrated in our material. These cases have been divided into three groups. Vessels with an internal diameter of over 2 mm in the film were described as wide, those with a diameter of 1 to 2 mm as average, and those of less than 1 mm as narrow. Among these 354 cases, the posterior communicating artery was wide in 137 (38.7 ± 2.6 %), average in 147 (41.5 ± 2.6 %), and narrow in 70 (19.8 ± 2.1 %). The corresponding incidence figures in relation to the 1 020 cases in the total material were 13.4 ± 1.1 % for the wide group, 14.4 ± 1.1 % for the average, and 6.9 ± 0.8 % for the narrow group.

As mentioned before, there were, in addition to the 354 cases in which the posterior cerebral artery was demonstrated, 55 cases in which the

posterior communicating artery alone was filled. Of these, only 2 were wide, 19 were average and 34 narrow. The total number of visible posterior communicating arteries and their widths will be seen from Table 1.

If PADGET's figures were universally applicable, one half to one third of all posterior communicating arteries would thus be demonstrated at carotid angiography and this would be so, irrespective of whether the vessels were wide, average or narrow.

Looking at the three groups of vessel diameters, distributed among internal carotid and common carotid angiographies (Table 1), we find that all three groups show a higher incidence of filling of the posterior communicating artery in the internal carotid examinations. The difference is of the same magnitude in the three groups.

According to several authors, the posterior cerebral artery is a branch of the internal carotid artery in about 20 % of cases. The posterior communicating and posterior cerebral arteries then form a vessel of uniform width while that portion of the circle of Willis which normally runs from the basilar artery to the junction of the posterior communicating and posterior cerebral arteries is narrow, or even entirely absent. In the remaining four-fifths of cases, according to these authors, the posterior cerebral artery is, anatomically speaking, a branch of the basilar artery; this would mean that the posterior communicating artery would be narrower than this vessel or, in exceptional cases, absent. All intracranial blood vessels, hence the posterior cerebral artery also, vary in width from case to case. With these anatomical facts in mind, the width of the posterior communicating artery is of little value when expressed in absolute values. The posterior communicating artery may, for example, have an internal diameter of over 2 mm and yet be much narrower than the posterior cerebral artery; similarly, it may have the same width as the posterior cerebral artery despite the fact that the bore is not over 1 mm. I therefore correlated the width of the posterior communicating artery with that of the posterior cerebral artery in cases where these vessels were demonstrated, and divided the 354 cases in this material into three groups. In the first group the lumen of the posterior communicating artery was of the same width as that of the posterior cerebral artery, in the second it was slightly narrower but not quite half as narrow, and in the third its diameter was one half, or less than one half of the corresponding measurement for the posterior cerebral artery. There were 217 cases (21.2 ± 1.3 %), i. e. more than half the total number, in the first group, 72 (7.1 ± 0.8 %) in the second, and 65 (6.4 ± 0.8 %) in the third. The material was also divided among internal carotid and common carotid angiographies and compared with the total 1 020 cases in the normal material, Table 2.

The incidence of cases with equally wide posterior communicating

Table 2

Conventional carotid angiographies. Comparison of the widths of the posterior communicating and posterior cerebral arteries in internal and common carotid angiographies

	Post. comm. art. of same width as post. cer. art.		Post. comm. art. slightly narrower than post. cer. art.		Post. comm. art. half as wide as, or narrower than post. cer. art.		Totals of contrast-filled arteries		Number of angiographies performed
	No.	%	No.	%	No.	%	No.	%	
Internal carotid angiography	144	24.1 ± 1.8	51	8.5 ± 1.1	53	8.9 ± 1.2	248	41.5 ± 2.0	597
Common carotid angiography	73	17.3 ± 1.8	21	5.0 ± 1.1	12	2.8 ± 0.8	106	25.1 ± 2.1	423
Totals	217	21.2 ± 1.3	72	7.1 ± 0.8	65	6.4 ± 0.8	354	34.7 ± 1.5	1 020

and posterior cerebral arteries is accordingly about as high as that mentioned by anatomists for subjects with a posterior cerebral artery considered to be a branch of the internal carotid artery. In the other two groups the incidence is much lower, corresponding to only a small percentage of the cases where the posterior cerebral artery anatomically speaking is regarded as a branch of the basilar artery; and even taking into consideration the few cases in which the posterior communicating artery is absent.

In all groups the incidence is higher in the internal carotid than in the common carotid angiographies. Relatively speaking, the difference is smallest among cases with a posterior communicating and posterior cerebral artery of equal width and largest in the group displaying the greatest difference between the widths of the two vessels.

Rapid serial carotid angiographies

Among the 232 rapid serial carotid angiographies the posterior cerebral artery was filled in 89 (38.4 ± 3.2 %). The incidence was thus slightly higher in the rapid serial angiographies than in conventional examinations. The difference is not significant, however. Retrograde filling of the basilar artery was observed in 6 instances (2.6 ± 1.0 %). This incidence was also higher than for the conventional carotid angiographies, although the difference is not significant here either.

In 16 rapid serial angiographies (6.9 ± 1.7 %) the posterior communicating artery was filled but not the posterior cerebral artery. This figure also was slightly higher than the corresponding figure in the conventional carotid angiographies. The difference is not significant.

As in the case of the conventional carotid examinations, there were no significant differences in the incidence of filling of the posterior cerebral artery between the two sexes nor as regards the side distribution. The age distribution was also largely the same as in the conventional material.

Contrast medium

During the period when these examinations were carried out two contrast media were used, Triurol 25 to 50 % (sodium acetrizoate) and Hypaque 45 % (sodium diatrizoate). The effect of the contrast medium on the filling of the posterior cerebral artery could be studied only in the rapid serial carotid angiographies since, in these, the same Triurol concentration — the 50 % solution — was used throughout. Triurol 50 % contains roughly 20 % more iodine per unit of volume than Hypaque 45 %. According to KÅGSTRÖM, LINDGREN & TÖRNELL, Triurol causes considerable vascular dilatation. This sets in at such a late stage, however, that it can have no conceivable effect on the filling of the posterior cerebral artery, unless perhaps towards the end of very slow injections.

The material contains 86 examinations carried out with Triurol and 146 with Hypaque. The same amount of both the contrast substances was injected. The posterior cerebral artery was visible in 33 (38.4 ± 5.2 %) of the Triurol cases and in 56 of the Hypaque cases (38.4 ± 4.0 %). No difference was observable despite the fact that the Triurol solution contained 20 % more iodine per unit of volume than Hypaque.

Site of puncture

In the material of rapid serial carotid angiographies, 119 were internal carotid and 113 common carotid examinations. The posterior cerebral artery was filled in 59 of the internal carotid angiographies (49.6 ± 4.6 %) and in 30 of the common carotid angiographies (26.5 ± 4.2). The difference is highly significant and is greater than in the conventional carotid angiographies. It was particularly in the internal carotid angiographies that filling of the posterior cerebral artery was more frequently observed.

Of the 6 examinations showing retrograde filling of the basilar artery 5 were internal carotid angiographies (4.2 ± 1.8 %) and one a common carotid angiography (0.9 ± 0.9 %). The figure obtained for the internal carotid examinations is 10 times higher than the incidence mentioned by KRAYENBÜHL & YAŞARGIL for retrograde filling of the basilar artery.

Among the 16 examinations in which the posterior communicating artery alone was filled, 10 (8.4 ± 2.5 %) were internal carotid and 6 (5.3 ± 2.1 %) common carotid angiographies.

Table 3

Rapid serial angiographies. Comparison of the widths of posterior communicating and posterior cerebral arteries in internal carotid and common carotid angiographies

	Post. comm. artery of same width as the post. cerebral artery		Post. comm. artery slightly narrower than post. cerebral artery		Post. comm. artery half as wide as, or narrower than post. cer. artery		Totals of contrast-filled arteries		Number of angiographies performed
	No.	%	No.	%	No.	%	No.	%	
Internal carotid angiography	31	26.0 ± 4.0	14	11.8 ± 3.0	14	11.8 ± 3.0	59	49.6 ± 4.6	119
Common carotid angiography	22	19.4 ± 3.7	6	5.3 ± 2.1	2	1.8 ± 1.2	30	26.5 ± 4.2	113
Totals	53	22.8 ± 2.8	20	8.7 ± 1.8	16	6.9 ± 1.7	89	38.4 ± 3.2	232

Diameter of posterior communicating artery

The diameter of the posterior communicating artery was directly compared with that of the posterior cerebral artery, the same norms being used as in the conventional angiographies. The percentage values have been calculated on the whole material of 232 cases. The posterior communicating artery was of the same width as the posterior cerebral artery in 53 cases (22.8 ± 2.8 %), in 20 (8.7 ± 1.8 %) it was slightly narrower, and in 16 (6.9 ± 1.7 %) it was half as narrow as the posterior cerebral artery, or even narrower. In all three groups these figures lay at a slightly higher level than the corresponding figures for the conventional angiographies.

This material was also divided up among internal carotid and common carotid angiographies, Table 3. As in the conventional angiographies (Table 2) the incidence was higher in internal carotid examinations in all groups. Here also, the difference was smallest, relatively speaking, when both vessels had the same diameter, and greatest when the difference between the two vessel diameters was greatest. This tendency was much more evident in the rapid serial angiographies than in the conventional series.

Duration of visibility of posterior cerebral artery

When studying the conventional carotid angiographies I had observed that the posterior cerebral artery could show striking differences when the injection was repeated under apparently similar conditions. In several instances, filling of the artery was observed at one injection while at another injection into the same vessel it was not demonstrated

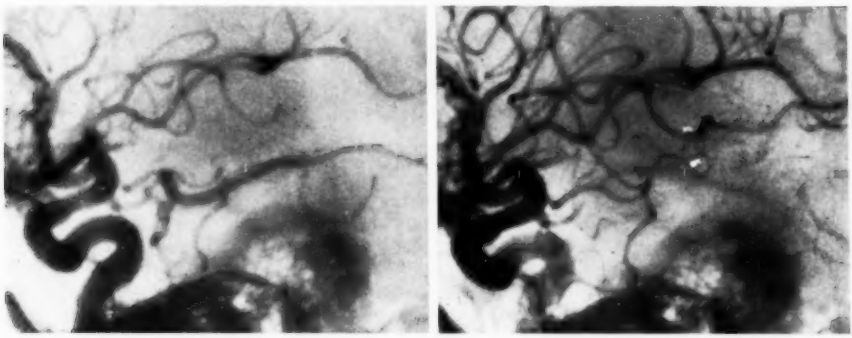

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Fig. 1. Roentgenograms from rapid serial angiography. a) During the injection of the contrast medium the posterior cerebral artery and a short portion of the basilar artery are visible. b) Immediately after termination of the injection only part of the posterior communicating artery is seen.

at all, or vice versa. An explanation of this phenomenon was obtained from the rapid serial angiographies. It was found that 52 of 89 (58.4 ± 5.2 %) contrast-filled posterior cerebral arteries were visible as long as contrast medium remained in the carotid siphon. In the remaining 37 cases (41.6 ± 5.2 %) the artery was demonstrated in only one or a few of the views showing contrast medium in the carotid siphon. The demonstration of the posterior cerebral artery coincided in all cases with the time during which the injection was in progress, as exemplified in the roentgenograms (Fig. 1). With a rapid injection, the injection time corresponded to the earlier part of the arterial phase.

Dividing these two groups of rapid serial angiographies between internal carotid and common carotid examinations, it was found that among 59 of the former type of examination with a contrast-filled posterior cerebral artery there were 30 (25.2 ± 4.0 %) in which the artery was visible as long as contrast medium was present in the carotid siphon while in 29 (24.4 ± 3.9 %) it emptied before the carotid siphon. Among 30 common carotid angiographies the corresponding figures were 22 (19.5 ± 3.7 %) and 8 (7.1 ± 2.4 %). These figures indicate that the incidence of cases where the posterior cerebral artery was visible for the same length of time as the carotid siphon was probably slightly higher in the internal carotid than in the common carotid angiographies. The difference is not significant, however. The difference was appreciably greater for cases where the posterior cerebral artery was visible only during the actual injection of the contrast medium. Here too, the incidence was higher in the internal carotid artery examinations. The difference is highly significant.

Table 4

Rapid serial carotid angiographies. Comparison of the widths of the contrast-filled posterior communicating and posterior cerebral arteries in relation to the duration of the visibility

	Post. comm. art. of same width as post. cer. art.		Post. comm. art. slightly narrower than post. cer. art.		Post. comm. art. half as wide as, or narrower than post. cer. art.		Totals	
	No.	%	No.	%	No.	%	No.	%
Post. cer. art. visible as long as carotid siphon was filled	40	44.9 ± 5.3	10	11.3 ± 3.3	2	2.2 ± 1.6	52	58.4 ± 5.2
Post. cer. art. visible only during injection	13	14.6 ± 3.7	10	11.3 ± 3.3	14	15.7 ± 3.9	37	41.6 ± 5.2
Total number of contrast-filled posterior cerebral arteries	53	59.5 ± 5.2	20	22.6 ± 4.7	16	17.9 ± 4.0	89	100

These two groups showing different durations for the demonstration of the posterior cerebral artery were also compared with the relations existing between the diameter of the posterior communicating and posterior cerebral arteries (Table 4). The general tendency was that when the posterior communicating and posterior cerebral arteries had the same diameter they were visible as long as contrast medium was available in the carotid siphon. The greater the difference in diameter between the two arteries the more often was the posterior cerebral artery visible only during the actual injection.

Vertebral angiographies

Anatomists consider that in more than 80 % of cases the posterior cerebral artery should be regarded as a branch of the basilar artery and hence that it belongs to the vertebral artery system. In the remaining approximately 20 % of all cases it is, as mentioned before, a branch of the internal carotid artery.

In carotid angiographies, a higher incidence of filling of the posterior cerebral artery was obtained than might have been expected in view of the anatomical investigations. This was so, even when only those cases were considered in which the roentgen anatomy justified the posterior cerebral artery being regarded as a branch of the carotid artery, in other words, when the posterior communicating and posterior cerebral arteries were equal in diameter.

Our material of 211 vertebral angiographies gave a similar result. Both posterior cerebral arteries were demonstrated in 185 instances (87.7 ± 2.3 %), in 22 cases (10.4 ± 2.1 %) one posterior cerebral artery

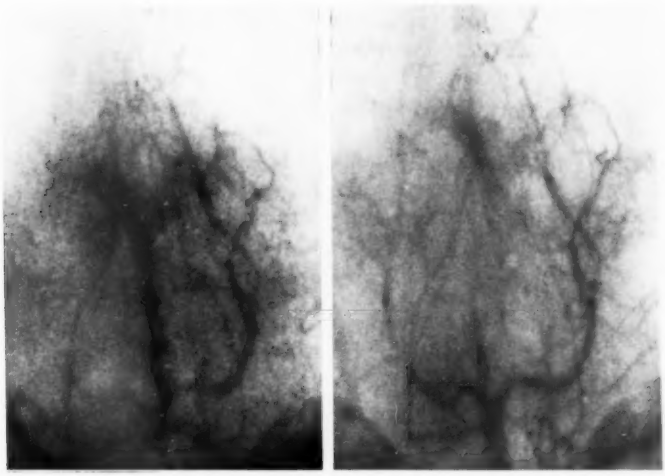

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Fig. 2. a) Puncture needle in unsatisfactory position. Only left posterior cerebral artery visible. b) Needle is now satisfactorily placed. Both the posterior cerebral arteries are well filled.

was shown, and in 4 (1.9 ± 0.9 %) none at all. These figures are in complete accord with those reported by KRAYENBÜHL & YASARGIL. More than 90 % of all posterior cerebral arteries were demonstrated. This means that a few arteries anatomically to be regarded as branches of the internal carotid artery were filled, also that many posterior cerebral arteries were visible at both carotid and vertebral angiography.

In all probability, these figures for the filling of the posterior cerebral artery in vertebral angiographies must be regarded as a little too low. It often happens that one or both of these arteries fail to fill if the puncture needle is in an unsatisfactory position (Fig. 2). The reason why both the posterior cerebral arteries were not visible in 26 cases is probably partly to be sought in inadequately placed needles.

At least one posterior communicating artery was visible in 110 instances (52.1 ± 3.4 %). Both were demonstrated with complete certainty in 21 instances (10.0 ± 2.1 %). It is probable, however, that both posterior communicating arteries were visible also in a few other cases, although superimposition made it impossible to distinguish them. The incidence of filling of the posterior communicating artery at vertebral angiography was somewhat lower in our material than that stated by KRAYENBÜHL & YAŞARGIL.

In 20 cases (9.5 ± 2.0 %) a visible amount of contrast medium had passed over into the carotid siphon.

Bilateral carotid angiographies as well as vertebral angiography were performed in the same case in 48 instances. In this part of the material it was seen that among the 7 cases where the posterior cerebral artery was visible in both carotid angiographies, filling of at least one posterior communicating artery was observed in 4 cases at vertebral angiography as well. Among 21 cases with filling of the posterior cerebral artery on one side at carotid angiography there were 2 in which both posterior communicating arteries were contrast-filled at vertebral angiography. These 6 cases demonstrate that in some instances it is possible at the angiographic examination to direct the radiopaque blood through the posterior communicating artery in both directions.

Among these 48 cases there were 19 carotid angiographies in which the posterior cerebral artery was visible and the posterior communicating and posterior cerebral arteries had the same diameter. Thus, from the viewpoint of the roentgen anatomy, the posterior cerebral artery appeared to be a branch of the internal carotid artery in these cases. In the corresponding 19 vertebral angiographies, the posterior cerebral artery in question was not filled in 11 instances and the anatomical and physiologic observations were thus in agreement. In the other 8 cases the posterior cerebral artery in question was, however, also visible at vertebral angiography.

Diameter of posterior communicating artery

When the visible posterior communicating arteries were divided up according to their diameter, using the same norms as in the carotid angiographies, the figures obtained among a total of 131 such arteries were 103 narrow (78.6 ± 3.6 %), 22 average (16.8 ± 3.3 %), and 6 wide (4.6 ± 1.8 %) vessels. There was thus an overwhelming majority of narrow posterior communicating arteries visible in the vertebral angiographies. It may be mentioned that in 2 of the 6 cases showing a wide posterior communicating artery, thrombosis was present in the internal carotid artery.

Conclusions

The posterior cerebral artery was more frequently demonstrated in this material of conventional carotid angiographies than in any other previously published series. This may have some connection with our injection technique, as we usually endeavour to inject the contrast medium into the internal carotid artery. In our material the posterior cerebral artery was more often visible in internal than in common carotid

angiographies. The incidence noted in the common carotid examinations was the same as in earlier investigations, which have been mainly based on this form of examination.

Other factors also affect the demonstration of the posterior cerebral artery. Puncture complications such as haematoma and extravascular injection of contrast medium seem to lower the incidence of filling of the artery. In this connection, preliminary experiments carried out by GREITZ are worthy of mention. After a carotid angiography at which the posterior cerebral artery was demonstrated he manually compressed the same carotid artery proximal to the puncture site and observed that the posterior cerebral artery was not visible on renewed injection. Such compression of the carotid naturally causes a pressure drop in the carotid artery distal to the compression site and thereby a difference in pressure between the carotid and vertebral arteries in favour of the latter vessel. It is highly probable that both haematomas and extravascular injections may produce a similar compressing effect. A close parallel to these observations, as WICKBOM, RUGGIERO and RIISHEDE have pointed out, will be found in the incomplete filling of the anterior cerebral artery when the injection needle is in an unsatisfactory position. SALTZMAN and KRAYENBÜHL & YAŞARGIL have shown that it is possible by vascular compression to direct the circulation in both directions through the posterior communicating artery.

The other variations in filling of the posterior cerebral artery could also be attributable to changes in the local blood pressure conditions. The injection of contrast medium would raise the pressure in the injected vessel to a higher level with a rapid than with a slow injection speed, and in internal carotid more than in common carotid angiography, in which the external carotid artery would take over a part of any pressure increase. It has previously been considered by several investigators that the injection of a contrast medium causes a pressure rise in the injected artery. GREITZ, however, when making intravascular pressure measurements, was unable to demonstrate any measurable pressure increase in the carotid artery at cerebral angiography, although he was not willing to exclude the possibility of a small, non-measurable pressure increase in the vessel. In GREITZ's investigations, the contrast medium and saline solution were in all cases but one injected into the common carotid artery.

Another reasonable explanation might be that a higher concentration of contrast medium in the carotid siphon is attained at internal carotid angiography than in a common carotid examination. The possibilities of filling the posterior cerebral artery with a visible concentration of contrast medium would thus be greater at internal than at common carotid angiography. The same explanation should be reasonably ap-

plicable to the difference between a rapid and a slow injection. A higher concentration of contrast medium in the carotid siphon is, admittedly, achieved with a rapid injection than with a slow one, but it has not been possible to observe any difference in the demonstration of the posterior cerebral artery between a more concentrated and more iodized contrast medium (Triurol 50 %) and a less concentrated substance containing less iodine (Hypaque 45 %). There would therefore seem to be some reason for submitting the question of possible pressure increases due to injection to renewed investigation, using a larger material and a method capable of detecting even minute pressure differences.

The demonstration of the posterior cerebral artery at carotid angiography is also influenced by the diameter of the posterior communicating artery. The relation between the diameters of the posterior communicating and posterior cerebral arteries seems to be the factor of greatest importance here. A comparison with earlier anatomical investigations would suggest that filling is achieved at carotid angiography in the vast majority of cases with posterior communicating and posterior cerebral arteries of equal diameter. In these cases there is probably even under normal conditions a flow of blood from the internal carotid to the posterior cerebral artery. The greater the difference in calibre between the posterior communicating and posterior cerebral arteries the less frequently are the vessels demonstrated at carotid angiography. In the few angiographies in which this has been observed it has almost exclusively been a question of internal carotid examinations. In these cases there is probably only an inconsiderable circulation in the posterior communicating artery even in normal circumstances. Only when the concentration of contrast medium is very high in the carotid siphon could possibilities exist for demonstration of the posterior cerebral artery at carotid angiography. This is the most feasible explanation if the injection of contrast does not cause any pressure increase in the carotid artery.

The posterior cerebral artery is more frequently demonstrated in rapid serial carotid angiographies than in conventional carotid examinations. The reason for this is that, in two-fifths of all cases in which the artery is visible, it is only seen as long as the injection of contrast medium is in progress, *i. e.* in practice, in the early part of the arterial phase. Hence, if at conventional carotid angiography the film is exposed in a relatively late arterial phase the posterior cerebral artery may already be devoid of contrast medium even though it was filled only a moment before. Further, it would seem logical to count on a pressure increase due to the injection, especially as the demonstration of the posterior cerebral artery, as regards duration, is strictly bound to the injection time.

These observations provide certain guiding principles as to how to plan a carotid angiography in order to achieve the best conditions for demonstration of the posterior cerebral artery.

1. An endeavour should be made to puncture the internal carotid artery.
2. The examination should be in the form of a rapid serial angiography.
3. The contrast medium should be injected rapidly. Short needles may be used in order to reduce the resistance on injection.
4. Puncture complications should be avoided as far as possible. In practice, this means that an experienced operator should perform the puncture if demonstration of the posterior cerebral artery is of special importance.
5. Compression of the vertebral artery may be applied.

When filling of the posterior cerebral artery is studied in vertebral angiographies it is noted that many of these vessels are filled in both carotid and vertebral examinations. This also applies to some of the posterior cerebral arteries which are filled through an equally wide posterior communicating artery at carotid angiography and which thus, roentgenanatomically, have the appearance of a branch of the carotid artery.

The posterior communicating artery is filled on one or both sides in more than one half of all vertebral angiographies. The vast majority of these contrast-filled vessels are narrow. In a few instances, filling of the same narrow posterior communicating artery was observed at both carotid and vertebral angiography. This indicates that there are cases — mainly with a narrow posterior communicating artery — in which the circulation through this vessel is inconsiderable and can take place in either direction.

SUMMARY

The posterior communicating and posterior cerebral arteries have been studied in a material consisting of 1 020 conventional carotid angiographies, 232 rapid serial carotid angiographies, and 211 vertebral angiographies. The results of the investigation are discussed and guiding principles suggested for achieving good filling of the posterior communicating and posterior cerebral arteries.

ZUSAMMENFASSUNG

Die Arteria posterior communicans und die Arteria cerebralis posterior sind an einem Material, das aus 1 020 konventionellen Karotisangiographien, 232 schnellen Reihenkarotisangiographien und 211 Vertebralisangiographien bestand, studiert worden. Die Untersuchungsergebnisse werden besprochen und Richtlinien werden vorgeschlagen, um eine gute Ausfüllung der Arteria communicans posterior und der Arteria cerebralis posterior zu erhalten.

RÉSUMÉ

L'auteur a étudié les artères communicante postérieure et cérébrale postérieure sur un matériel comprenant 1 020 angiographies carotidiennes ordinaires, 232 angiographies carotidiennes en série rapide et 211 angiographies vertébrales. Il examine les résultats de cette étude et propose des principes directeurs permettant d'obtenir un bon remplissage des artères communicante postérieure et cérébrale postérieure.

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CONTRAST EXAMINATION OF THE LUMBAR INTERSPINOUS LIGAMENTS

Preliminary report

by

Rolf Köhler

Low backache, with or without referred pain in the lower extremities, has been the subject of considerable attention during the last three decades. A major advance in this field was reached with the acceptance of root compression following prolapse of a disc as the most frequent cause of sciatica; and since then this has tended to overshadow the importance of the posterior lumbar region and, in particular, the supraspinous and interspinous ligaments as the possible sites of symptoms.

BAASTRUP (1933) was one of the first to show a clinical interest in the lumbar spinous processes and the intervening tissues. KELLGREN (1939) made an attempt at mapping the changes in the interspinous ligaments by means of intraligamentous injections of a fluid.

MAGNUSON (1944) and NEWMAN (1952) were of the opinion that strain on the lumbar ligaments and injury to the supra- and interspinous ligaments constituted the commonest cause of low backache. The latter also suggested that a 'sprung back', as he called this condition, might be a precursor of disc protrusion; he stated that a torn or defective supraspinous ligament was almost invariably found at operation for prolapsed

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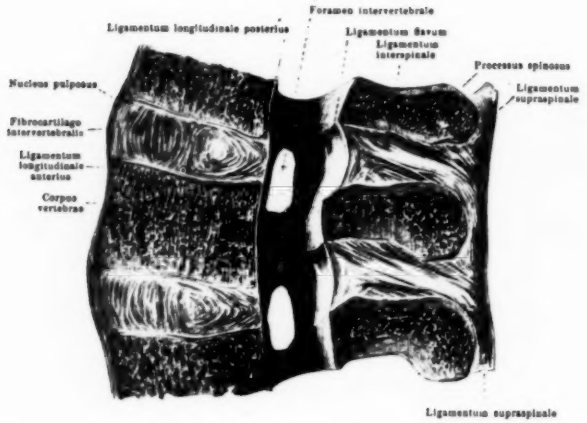


Fig. 1. Median section through the lumbar spine showing the supraspinal and interspinous ligaments (after SPALTEHOLZ).

disc. HACKETT (1958) stressed the importance of a relaxation of the interspinous ligament L 5—S 1 as a cause of prolonged and refractory low backache.

In this clinic KALLIO has for many years carefully studied the lumbar interspinous ligaments in connection with operations for prolapsed disc. In a great many cases he has found relaxed supraspinous ligaments and at the same time stretched or fat-infiltrated, obviously degenerative interspinous ligaments which, moreover, have often exhibited obvious defects. The findings were localized to the two lowest interspinous spaces. He has observed increased mobility in the corresponding segment as well as new bone formation at the margins of the spines. Since the autumn of 1957, he has carried out cutaneous ligamentous reconstruction in some of these cases, a method which has also been experimentally tested in rabbits (JOKINEN 1958).

These observations and the need for a preoperative diagnosis of such changes were the reasons for the present investigation.

Method of examination

The normal anatomy of the ligaments of the lumbar spine is demonstrated in Fig. 1. The space between two spinous processes is filled in the sagittal plane by a ligamentous wall. The fulcrum of the 'Bewegungssegment' lies within the area of the small joints.

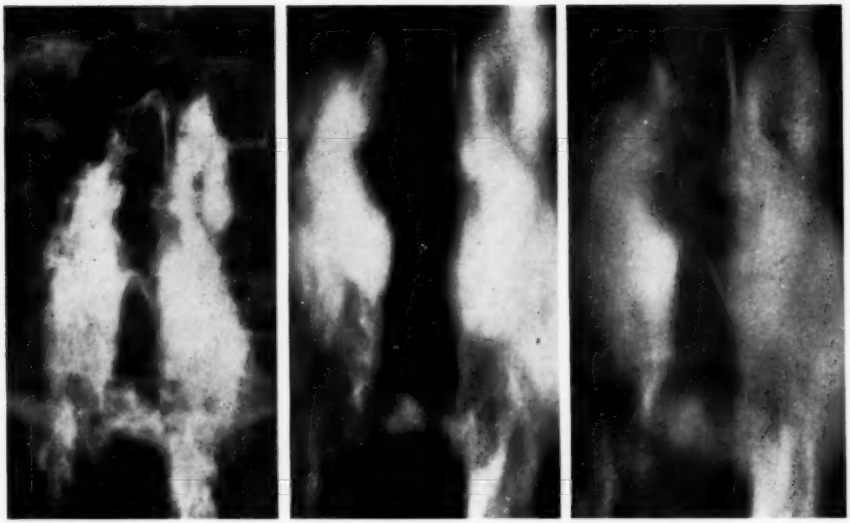
Fig. 2. Wide, bilateral, vertical streaks of contrast medium separated by the spinous processes and the interspinous ligaments, these latter appearing in the shape of somewhat spindle-shaped filling defects. Normal findings.

RISSANEN has begun an extensive pathological investigation of lumbar interspinous ligaments in cadavers. Fifty-five children, aged 0 to 10 years, with normal skeletons, proved to have quite undamaged, tense, shining ligaments. In about 100 adults, entirely normal findings alternated with ligamentous deviations of various kinds, all the changes being localized to the three lowermost interspinous spaces. The observations made in the child material appear to warrant the statement that such changes in the adults are pathologic, and they afford no evidence that defects in the ligaments are to be accepted as a normal anatomical feature.

Measurements of the distance between the spinous processes at maximal lumbar extension and flexion, with the patient in the lateral position, did not prove satisfactory. To make a direct study of the ligaments possible, injection of a positive contrast medium was therefore attempted. Under normal conditions there should be an impermeable ligamentous wall in the midline and by injecting contrast medium bilaterally along this wall and taking a.p. views of the area it should be possible to demonstrate: (1) the contours of the ligament and thus its transverse dimension, (2) possible ligamentous defects since the contrast medium would flow into the ligament.

During 1958, 100 cases were examined by this method. In the first 60 cases the contrast medium was injected unilaterally and on the side of the patient's main symptoms. It was believed that in this way a defect would be best revealed by flow of contrast medium to the uninjected side. Bilateral injection, however, eventually proved to give a more complete result without loss of the advantages gained by the earlier method. Since then the bilateral injection technique has been employed exclusively and at present is as follows.

The patient is placed in a lateral position on the Bucky table, with the lumbar spine flexed. The three lowermost interspinous spaces are palpated and marked and the skin is cleansed. A 20 ml syringe fitted with a No. 12 needle and filled with 1 % xylocaine — exadrine is em-



a b c

Fig. 3. a) Broad communication in the L 5—S 1 interspinous space. The contrast medium is irregularly distributed and varies in density, as is generally the case in degenerated fat-infiltrated ligaments. b) Tomogram 3 cm. c) Tomogram 4 cm.

ployed for the injection. A small quantity of the anaesthetic is injected subcutaneously in the midline over the L 5—S 1 interspinous space. The needle is then introduced to its entire length at right angles to the skin but 0.5 to 1 cm lateral to the midline in the sagittal plane along the interspinous ligament.

The needle first encounters a certain amount of resistance but after it has penetrated a distance of about 1 cm this is reduced, provided the ligament has not been penetrated. Five to 7 ml of the anaesthetic are then injected and the procedure is repeated on the opposite side. The two nearest ligaments above are similarly treated. By placing the tip of the index finger on the adjacent spinous process it is easy to locate the ligament, provided the subject is not too obese.

The series of injections is repeated 10 to 15 minutes later with a contrast medium substituted for the anaesthetic, 4 to 5 ml of the medium being introduced in the same way as close as possible to the ligamentous wall. We have mostly used a 20 per cent monoiodized water-soluble preparation (Conturex, Lundbeck, Kontrast-U, Leo) chiefly in order to prevent injury in the event of its accidental introduction into the lumbar canal. (We employ the same preparations for lumbar myelography.)

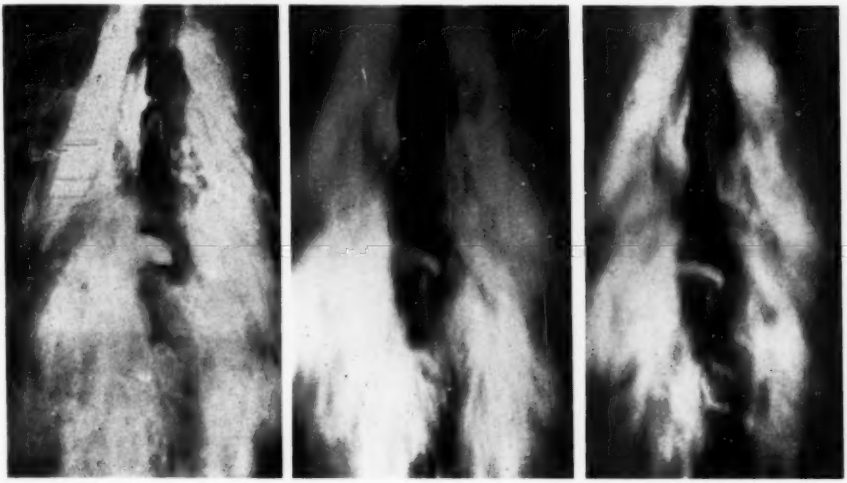


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Fig. 4. a) Insignificant penetration of contrast medium into the right L 3—4 ligament. Wide, homogeneous protrusion of contrast medium into the right half of the L 4—5 ligament which bulges to the left. Numerous streaks of contrast medium in the L 5—S 1 ligament together with a rounded accumulation centrally. At operation a deep, non-penetrating right-sided defect was found in the L 4—5 interspace. The ligament at the L 5—S 1 level was markedly relaxed and thin, with a cavity in the centre which communicated on both sides with the periligamentous tissue. b) Tomogram 2 cm. c) Tomogram 3 cm.

The density obtained has been satisfactory, but since accidents need hardly be feared a slightly more concentrated preparation such as Urografin 30 % is perhaps to be preferred; this has considerably improved the quality of the films in our latest ten cases.

After injection of the contrast medium, a roentgenogram is obtained in the a.p. projection with the patient supine and with the lordosis reduced as much as possible. In positive cases, tomography (2 to 5 cm sections) was performed with the patient in the same position. The contrast medium is for the most part absorbed within an hour.

Roentgenographic findings

A well-defined contrast-free zone, usually slightly spindle-shaped and 3 to 10 mm wide, is in normal cases observed between the spinous processes (Fig. 2).

In pathologic cases, the contours of the contrast medium are often slightly irregular or ill-defined. A blotched or streaked penetration of contrast medium into the ligamentous area probably corresponds to degenerative changes in the ligament (Figs. 3 and 4). Occasionally, a

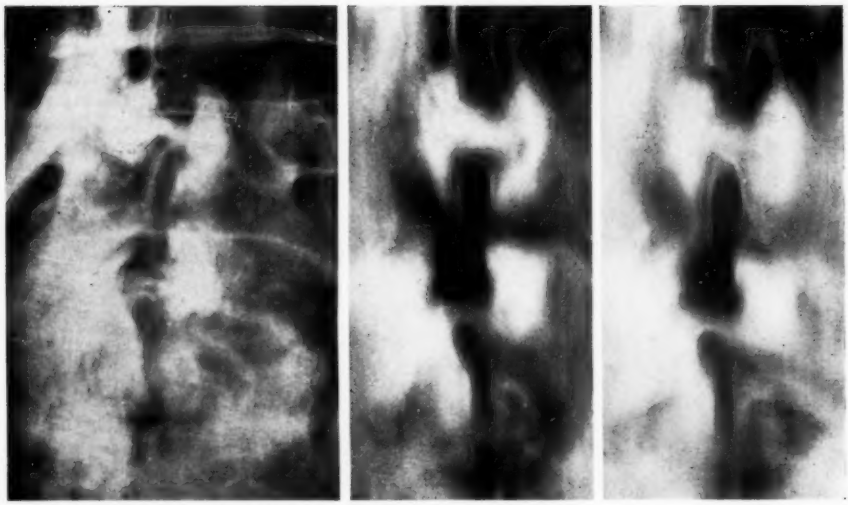

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Fig. 5. The contrast medium fills up the greater part of the L 3—4 and L 4—5 interspinous spaces. Operation disclosed columnar defects in the corresponding ligaments. (Spondylodesis was performed.) b) Tomogram 3 cm. c) Tomogram 4 cm.

unilateral rounded bulging of contrast medium towards or slightly past the midline is seen, without, however, any direct communication between the two deposits. There is then a defect only within one half of the ligament (Fig. 4, L 4—5, interspinous space). Total rupture of the ligament usually occurs near the upper spinous margin. A homogeneous accumulation of contrast medium then occupies a greater or lesser part of the interspinous space (Fig. 5) and there is thus a connection between the deposits on the right and left sides.

Of the 100 cases examined, 55 were operated on, the majority under the diagnosis of prolapsed disc. The roentgenographic findings corresponded well with the operative findings, provided the contrast medium had been correctly deposited close to the ligamentous wall. Nineteen out of the 55 surgically treated cases had normal ligaments in the L 3—4—5 interspinous spaces. In one patient a prolapse was seen in the L 3—4 space, in 10 in the L 4—5 space and in 4 in the L 5—S 1 interspinous space, while 3 had symptoms of sciatica without any prolapse being found. Thirty-six cases exhibited pathologic ligaments at one or several of the interspinous spaces mentioned, 8 in the L 3—4 space, 21 in the L 4—5 space and 20 in the L 5—S 1 space. A pathologic ligament and prolapse at the same level were present in 20 cases and at different levels in 7 cases.

SUMMARY

A method for roentgen examination of the lumbar interspinous ligaments, based upon the injection of a contrast medium close to the ligaments on both sides, is presented. A hundred consecutive cases of low backache or sciatica have so far been examined. In normal cases the ligament appears as a flat spindle-shaped filling defect bounded by contrast medium; in pathologic cases the contrast medium penetrates into the ligament through defects.

ZUSAMMENFASSUNG

Eine röntgenologische Methode zur Untersuchung der lumbalen Interspinalligamente wird vorgelegt. Sie basiert auf der Injektion eines Kontrastmittels dicht an beide Seiten des Ligamentes. Einhundert fortlaufend registrierte Fälle mit Kreuzschmerzen oder Ischiasbeschwerden sind bisher untersucht worden. In normalen Fällen hat das Ligament das Aussehen eines flachen, spindelförmigen Füllungsdefektes, welcher vom Kontrastmittels begrenzt ist. In pathologischen Fällen dringt das Kontrastmittel durch Defekte in das Ligament ein.

RÉSUMÉ

L'auteur présente une méthode d'examen radiographique des ligaments interépineux lombaires, basée sur l'injection d'un moyen de contraste au voisinage des ligaments, des deux côtés. Ils ont examiné cent cas consécutifs de lombalgie ou de sciatique. Dans les cas normaux, le ligament se présente comme une clarté en fuseau allongé, entourée par le moyen de contraste; dans les cas pathologiques le moyen de contraste pénètre dans le ligament par des brèches.

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OPERATIVE INTESTINAL ARTERIOGRAPHY IN THE DIAGNOSIS OF DIVERTICULITIS OF THE COLON

by

Robert Schobinger

The diagnosis of malignant tumors and benign inflammatory lesions of the colon can usually be established without great difficulties. However, even in the course of a laparotomy, a benign inflammatory mass involving the colon may occasionally only questionably or not at all be differentiated from a malignant neoplasm. Malignant intestinal neoplasms (SCHOBINGER et coll. 1957, 1958) are characterized by certain well defined angiographic criteria; it is the purpose of this communication to present the angiographic appearances of diverticulitis of the large intestine, as the demonstration of a vascular pattern typical for diverticulitis, and different from that of carcinoma, would assume diagnostic importance.

Technical considerations. The contrast medium employed was a 50 % solution of Hypaque (sodium 3,5 diacetamido — 2,4,6 triiodobenzoate) (generously supplied by Winthrop Laboratories, Inc. New York, N. Y.). The intra-arterial injections carried out during laparotomy were performed according to previously outlined principles. The only modification of the technique consisted in the retrograde introduction of a plastic catheter into a sigmoidal artery up to the point of origin of the latter from the inferior mesenteric artery. Since very satisfactory arteriograms

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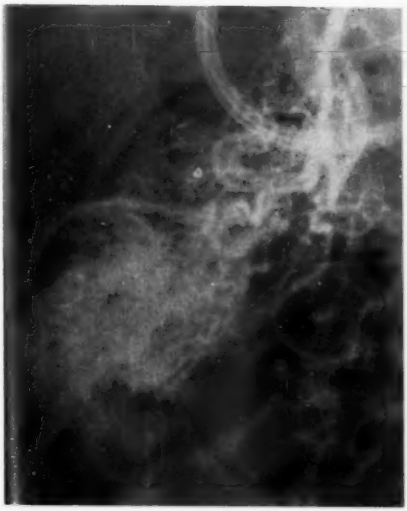

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Fig. 1. Adenocarcinoma.

a) Barium enema. Typical change in transverse colon. Gross specimen superposed on the film.

b) Operative intestinal arteriogram through midcolic artery, arterial phase. Tumor wall well outlined by collection of abnormal vessels and puddling of contrast medium. Adjacent intestinal vessels normal.

c) Venous phase, film exposed 10 sec after the end of injection. Residual collection of contrast medium within neoplasm.

were obtained in most instances by this method it was rarely necessary to puncture the main trunk of the inferior mesenteric artery. This technical refinement tends to avoid the possibility of bleeding from the punctured inferior mesenteric artery since the respective sigmoidal artery can be safely ligated after withdrawal of the catheter.

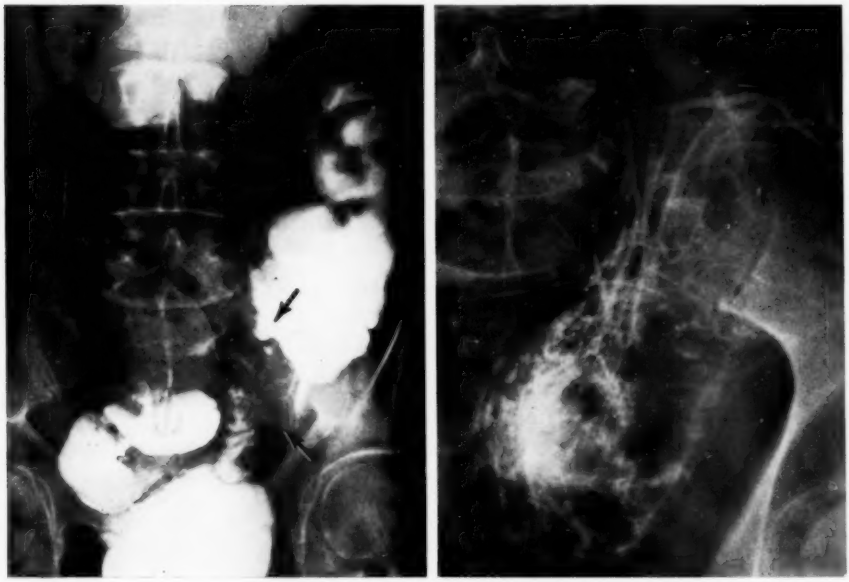

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Fig. 2. Diverticulitis. a) Barium enema. Partially obstructing lesion in sigmoid colon (arrows) with fistula into small intestine. b) Laparotomy 2 months later. Operative intestinal arteriogram, arterial phase, injection into sigmoidal artery. Hypervascularization of area of inflammation without abnormal vessels or puddling of contrast medium. (Venous phase normal.)

Differential diagnosis

The difference between the angioarchitecture of carcinoma and that of diverticulitis is well demonstrated in the accompanying illustrations.

Carcinoma. The dynamic arterial phase of the operative intestinal arteriograms corresponds to the static angiogram of the injected specimens. All examined malignant lesions did exhibit a vascular pattern similar to the one previously reported. The latter is characterized by puddling of contrast medium within the neoplasm, and by the presence of vessels which are abnormal in size, number and configuration. These vascular changes appear to be strictly limited to the cancerous growth and are in strong contrast to the angioarchitecture of the surrounding normal intestinal wall. These studies, furthermore, confirm that the hypervascularized areas are limited to the actively growing portions of the neoplasm while the necrotic areas are avascular.

Fig. 3. Diverticulitis. Operative intestinal arteriogram through sigmoidal artery. The vascularization of sigmoid colon closely resembles that of adjacent non-inflamed large intestine.

Diverticulitis. The arteriographic picture of this benign inflammatory condition, which clinically may mimick carcinoma, fails to exhibit the vascular anarchy which is a characteristic of malignant tumors.

In correlating the degree of intestinal inflammation with the arteriographic appearances, slight differences could be noted in the density of the vascular network. Very mild degrees of inflammation exhibited an angiographic appearance almost identical to that of the surrounding normal bowel (Fig. 3). More acutely inflamed segments of colon had vascular changes corresponding to the degree of inflammatory hyperemia and accompanying hypervascularity (Fig. 2b). The individual vessels, however, did not show the abnormal alterations typically present in carcinoma, neither was there any puddling of contrast medium within the segment of intestine affected by diverticulitis. Additionally, the prolonged retention of contrast material observed in carcinomatous lesions, and arterio-venous shunts at the level of the cancer, could not be identified in the cases of diverticulitis examined.

Conclusions

Operative intestinal arteriography allows the roentgenographic evaluation of normal and diseased bowel. Studies carried out with this newer diagnostic approach and supplemented by control injections into resected specimens tend to substantiate the previously reported vascular anomalies

typical of malignant neoplasms. The vascular pattern of diverticulitis of the colon is distinctly different from the one observed in malignant processes. The only abnormality detected by operative intestinal arteriography, as well as by injections into specimens, consisted of variations in the density of the vascular network which otherwise, however, exhibited no pathologic features.

Operative angiography of the intestinal tract has been found to be a valuable diagnostic aid in detecting the presence and/or determining the local extent of intestinal malignancies. Its scope now encompasses the differential diagnosis between cancer and benign inflammation. It can be anticipated that the correlation of refined vascular studies in vivo and on specimens with a detailed histologic evaluation of the angioarchitecture of intestinal lesions will yield more complete overall information concerning the hemodynamics within the diseased intestinal tract.

SUMMARY

Operative intestinal arteriography allows the roentgenographic evaluation of normal and diseased bowel. Studies supplemented by control injections into resected specimens tend to substantiate the previously reported vascular anomalies typical of malignant neoplasms. The vascular pattern of diverticulitis of the colon is distinctly different from the one observed in malignant processes. Operative angiography of the intestinal tract now encompasses the differential diagnosis between cancer and benign inflammation.

ZUSAMMENFASSUNG

Die operative intestinale Arteriographie gestattet die röntgenologische Beurteilung des normalen und krankhaften Darmes. Ergänzende Studien nach Kontrollinjektionen in resezierte Präparate tragen dazu bei, die früher berichteten, für maligne Erkrankungen typischen Gefässanomalien zu bekräften. Das Gefässbild einer Divertikulitis des Dickdarmes unterscheidet sich distinkt von dem bei malignen Prozessen beobachteten Bilde. Die operative Angiographie des Intestinums umfasst jetzt die Differentialdiagnose zwischen Karzinom und gutartiger Entzündung.

RÉSUMÉ

L'artériographie intestinale per-opératoire permet l'examen radiographique de l'intestin normal et pathologique. Nos études, complétées par des injections de contrôle dans les pièces réséquées, tendent à confirmer les anomalies vasculaires typiques des néoplasies malignes que nous avons rapportées précédemment. La disposition vasculaire de la diverticulite colique est nettement différente de celle qu'on observe dans les tumeurs malignes. L'angiographie per-opératoire du tractus intestinal permet donc maintenant le diagnostic différentiel entre cancer et inflammation bénigne.

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CATHETERIZATION AND SELECTIVE ROENTGENOGRAPHIC DEMONSTRATION OF THE LEFT VENTRICLE OF THE HEART

by

H. E. Hanson, Gunnar Jönsson and *Johan Karnell*

The method for performing selective angiocardiography that we described in 1949 was based on the principle that the contrast medium should be injected through a catheter into the area to be investigated or, if this could not be done, as close to that area as possible. When the left atrium and ventricle were to be examined, the contrast medium was injected into the pulmonary artery, experience having shown that clear roentgenographic demonstration of the left heart chambers could also be achieved by injection into this artery. An illustration of this may be found in ARVIDSSON's monograph on angiocardiography in mitral valvular disease. The need for direct examination of the left heart chambers with a catheter or cannula is nevertheless becoming steadily higher on account of the constantly increasing demands from heart surgeons for exact information about the anatomy and haemodynamics of the different parts of the heart. Selective examination of the left ventricle, including pressure measurements and roentgenographic demonstration by means of direct injection of a contrast medium, has now become as important a part of

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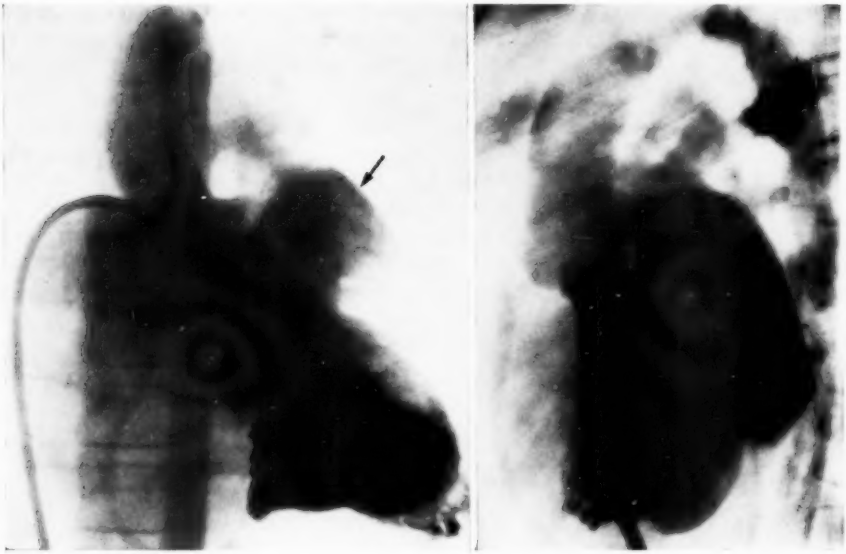


a) A. p. view b) Lateral view

Fig. 1. Large atrial septal defect with insufficiency in the atrioventricular plane; a persisting atrioventricular canal. The catheter was passed through the septal defect and mitral orifice and down into the left ventricle. When its tip was in the lowermost part of the ventricle, Urografin (1 ml/kg body weight) was injected. Regurgitation from ventricle to atria has taken place. Diagnosis confirmed at operation.

the pre-operative cardiac investigation as was ever the examination of the right side of the heart. The methods used are not new. The following review of earlier contributions to the technique is not presented with claims to completeness. Animal experiments are not mentioned.

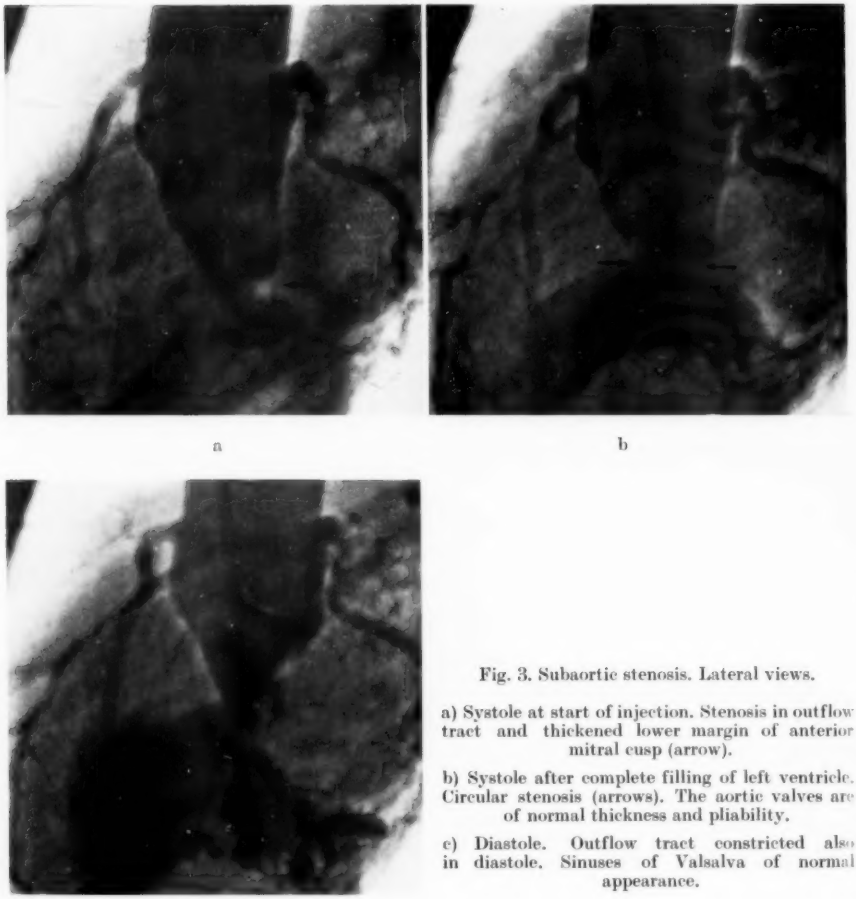
As early as 1936 NUVOLI injected a contrast medium into the left ventricle through a cannula inserted through the anterior wall of the thorax. In 1951 NUÑEZ & PONSDOMENECH demonstrated, on the basis of a number of successful examinations carried out without serious complications, that the method is not as dangerous as could be expected. Other investigators have subsequently confirmed that the technique may be used in all cases in which it is desirable to obtain information on the anatomy of the left ventricle and its orifices (SMITH, WILSON, CREGG & KLASSEN; LEHMAN, MUSSER & LYKENS). Pressure measurements have also been carried out with this method.

During the ten years or more that we have been catheterizing the ascending aorta for thoracic aortography we have found that the catheter

a) Systole, a. p. view b) Diastole, a. p. view

Fig. 2. Aortic valvular stenosis. The fused cusps form a dôme-shaped bulge into the aorta during systole. Post-stenotic dilatation visible in the ascending aorta. Sinuses of Valsalva visible during diastole. Valves slightly thickened. Ventricular wall hypertrophied, measuring 12 to 13 mm (normally, max 10 mm).

can be readily manoeuvred past the aortic valves and down into the left ventricle. RADNER in 1949 described a catheter specially designed for examination of the left ventricle. In 1950 ZIMMERMAN, SCOTT & BECKER catheterized the left ventricle without complications in 11 patients with syphilitic aortic insufficiency. An attempt to perform the same examina-



a b

c

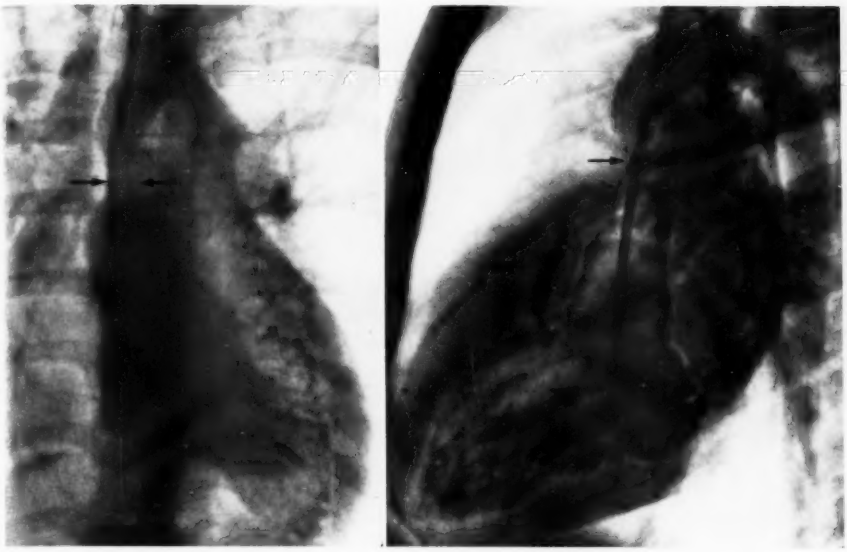
Fig. 3. Subaortic stenosis. Lateral views.

a) Systole at start of injection. Stenosis in outflow tract and thickened lower margin of anterior mitral cusp (arrow).

b) Systole after complete filling of left ventricle. Circular stenosis (arrows). The aortic valves are of normal thickness and pliability.

c) Diastole. Outflow tract constricted also in diastole. Sinuses of Valsalva of normal appearance.

tion in a patient with active rheumatic myocarditis led to ventricular fibrillation and a fatal outcome. Our own catheterizations of the left ventricle were to begin with more or less accidental. It is only since 1953 that selective examination of the left ventricle has become a part of our practical clinical work. Simultaneously with us, and partly on the basis of mutual discussions, PORSTMANN, GEISSLER & WOLF have also practised catheterization of the left ventricle, and in October 1958 published a large, well-documented material of aortic valvular disease and subaortic stenosis.



a) A. p. view b) Lateral view

Fig. 4. Supravalvular aortic stenosis. Directly above the origin of the coronary arteries the aorta is constricted for a length of approx. 1 cm (arrows). Ventricular wall is hypertrophied.

They used the common carotid artery for introduction of the catheter, however, and this seems to involve unnecessary risks. Catheterization of the ascending aorta and left ventricle can be performed, as we now know, through less dangerous routes and it may be regarded as established that the method is both practical and easy.

Our reason for preferring catheterization to transthoracic puncture is that the former accords better with the technique we use for other examinations of the heart and great vessels. Its greatest advantage is that the pressure measurements may be carried out without haste and, with the catheter in position, there is time to give careful consideration to the question of where and how the contrast medium should be injected to obtain the best results. The catheter method permits curves to be taken during the withdrawal of the catheter; another advantage is that the pressure can be measured both at rest and during exercise. The position of the catheter may also be utilized for the injection of isotopes or dye for the registration of dilution curves.

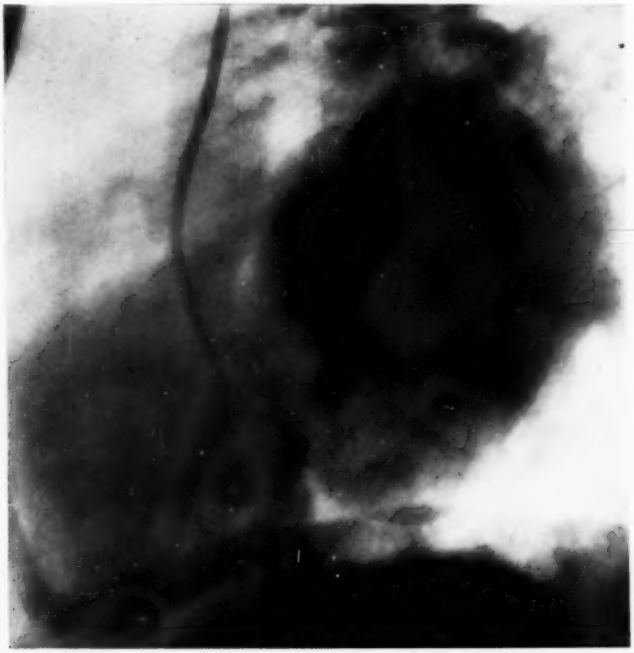
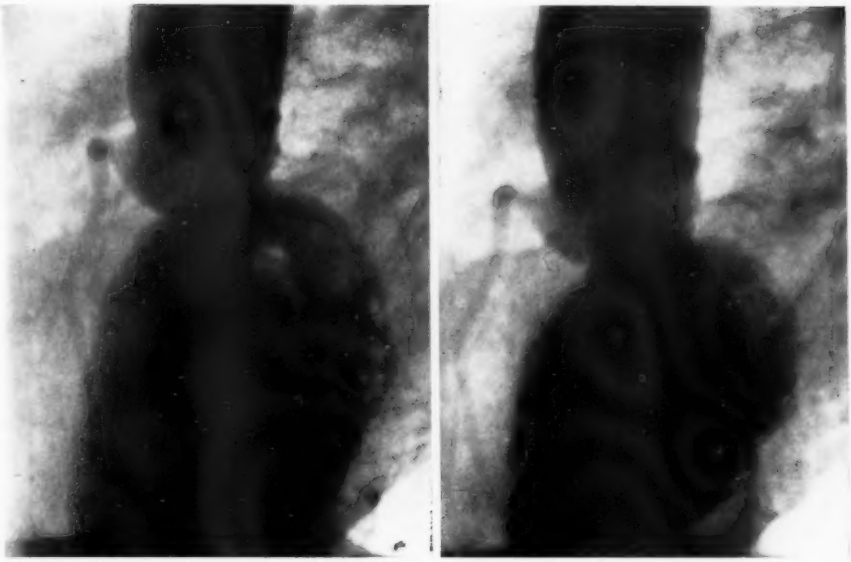


Fig. 5. Lateral view. Mitral incompetence. Considerable regurgitation from left ventricle to atrium, both greatly dilated.

Indications for catheterization

In what follows, the pathologic conditions in which catheterization of the left ventricle provides valuable information are briefly enumerated. In order to achieve the best results, the technique should be varied according to the nature of the case. In some instances, for example, the pressure recording is the most important factor in the investigation, in others the examination with a contrast medium; in others again the solution should be injected into the left ventricle, or into the ascending aorta.

1. *Ventricular septal defect* with left-to-right shunt. After samples have been taken for blood oxygen analysis and the pressure measured, a contrast medium should be injected into the ventricle for demonstration of the defect. We have no case of this type in our material.

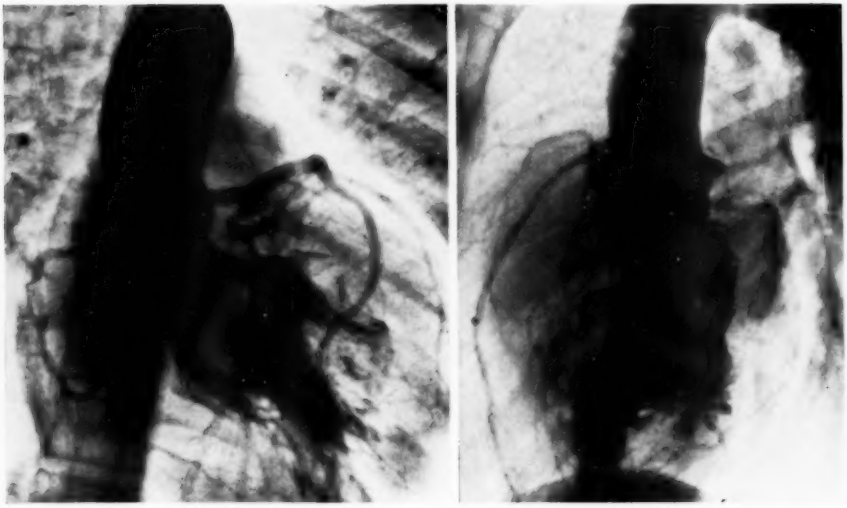


a) Diastole b) Systole

Fig. 6. Mitral and aortic valvular stenosis. The fused mitral cusps balloon into superior, dorsal portion of ventricle during diastole. Sinuses of Valsalva of normal appearance. The mitral cusps close tightly during systole excluding possibility of mitral incompetence. Systolic murmur was due to slight aortic valvular stenosis. Thickened valves, no normal unfolding, but stenosis not severe enough to cause a pressure gradient.

2. *Atrial septal defect involving the inferior portion of the septum.* Whenever such defects of the lower part of the atrial septum are present abnormalities in the atrioventricular valves are common — a persistent interatrial foramen primum with a common atrioventricular canal. This malformation may probably be most easily observed, or ruled out, if the contrast medium is injected into the left ventricle (Fig. 1).

3. *Aortic valvular stenosis.* The most important factor here is the determination of the pressure in the left ventricle, ascending aorta, and aortic arch. Roentgenographic demonstration of the aortic valves and their movements is, however, also necessary; this may be achieved by injection of contrast medium into the left ventricle, as PORSTMANN et coll. have demonstrated, but according to our experience the valves can be just as satisfactorily studied if the medium is injected into the ascending aorta (ODMAN & PHILIPSON). When the stenosis is marked, the catheter cannot be passed down into the ventricle and hence no pressure recordings can



a) A. p. view b) Lateral view

Fig. 7. Tumour of the myocardium. Wall of left ventricle greatly thickened and entire ventricle deformed. Considerable distance between coronary arteries and internal wall of ventricle owing to tumour.

be made in this chamber. Such cases seem to be surprisingly rare, and in these it may be indirectly concluded that the pressure in the ventricle is very high. The feature of greatest importance is to ascertain the pressure gradient between ventricle and aorta, in cases in which the stenosis is not too far advanced, and in these we have always succeeded in manoeuvring the catheter into the ventricle (Fig. 2).

4. *Subaortic stenosis.* The pressure is measured in the same way as in aortic valvular stenosis. In order to demonstrate the stenosis, a procedure indispensable to a correct diagnosis, the contrast medium should be injected into the lower part of the ventricle. These cases are numbered among those in which selective examination of the left ventricle is of particular value (Fig. 3).

5. *Aortic valvular incompetence.* The pressures in the aorta and ventricle are recorded in the same way as in the preceding cases. An examination by injection of contrast medium into the left ventricle gives no information of importance. The degree of regurgitation and the defective closure of the valves may be assessed with greater certainty if the solution is injected into the ascending aorta (JÖNSSON, BRODÉN & KARNELL; ÖDMAN & PHILIPSON).

6. *Mitral valvular disease with insufficiency.* Although it is possible to diagnose mitral insufficiency and estimate its degree with considerable certainty by ARVIDSSON's method of studying the left atrium and ventricle by injection of contrast medium into the pulmonary artery, injection into the left ventricle is the more exact method for determining the degree of regurgitation in mitral valvular disease with insufficiency. Both methods permit observation of the anatomy and motion of the mitral valves (Fig. 5).

7. *Combined left heart valvular disease.* In patients with various combinations of valvular disease of the mitral and aortic orifices roentgenographic demonstration of the left ventricle is the only method capable of producing an exact diagnosis. As in the case of simple mitral valvular disease contrast-filling may be achieved by injection into the pulmonary artery, but selective injection directly into the ventricle gives more accurate information; the aortic valves in particular are more clearly shown. Pressure measurements in the aorta and ventricle make it possible to assess the haemodynamic significance of any aortic constriction that may be present. Pathologic changes in the aortic valves should be possible to diagnose at an earlier stage with angiocardiography or aortography than with any other method, and this long before they give rise to clinical symptoms or abnormal pressures. Selective catheterization and demonstration of the left ventricle is indispensable in combined left heart valvular disease (Fig. 6).

8. *Pathologic lesions in the ventricular wall* (tumours, fibroelastosis) (Fig. 7).

Technique

We usually insert the catheter through the radial artery after exposure of the vessel; the artery is ligated when the catheter is removed after the examination. The necessity of sacrificing the artery may seem to be a drawback, but in all the hundreds of cases in which we have catheterized through the radial artery we have never registered any detrimental subjective or clinical effects. If it seems undesirable to damage this vessel, a larger artery may be selected, the catheter being introduced percutaneously by SELDINGER's method, but with this procedure it is more difficult to manoeuvre the catheter through the aortic orifice, and we have found that the advantages of using the radial artery outweigh the disadvantages.

We use a soft and thin-walled catheter, and there is no risk of damaging the aortic valves when the tip strikes against them; because of the thin-

ness of the walls, the canal is wide enough to allow the injection of contrast medium at a speed of 25 to 30 ml per second at a relatively low pressure. As the catheter has four side holes but no opening at the tip the contrast stream is dispersed and there is no risk of causing damage to the myocardium by a jet stream. Throughout the examination the cardiac activity is kept under observation with a cardioscope. The catheter is passed in as far as the aortic arch, where the first pressure recording is made; this is followed by measurement of the pressure in the ascending aorta. The catheter is then manoeuvred till its tip strikes against the valves; this may be both seen and felt. The tip should not be allowed to remain still in this position, but should be moved up and down rhythmically in order to prevent that it be caught in the opening of one of the coronary arteries. If the catheter is pushed down towards the aortic orifice in this way, the valve level is soon reached during a systole, when the orifice is open, and it is possible to manoeuvre the catheter without difficulty into the ventricle. After the tip has passed into the conus arteriosus the cardioscope records a more or less large number of ectopic beats. These disappear when the catheter is pushed further down into the ventricle but return when the tip comes into contact with the myocardium deeper down in the ventricle. A regular rhythm may be restored by drawing the catheter back a few centimetres. With the catheter in this position the pressure is measured, after which there is time to consider without undue haste any other procedure to be undertaken: whether contrast medium should be injected, and if so, whether into the ventricle or the aorta. If injection into the ventricle is decided upon the catheter is allowed to remain with its tip in the central portion of the ventricle, an automatic pressure syringe is connected, and contrast medium injected.

The amount of solution injected varies a little according to the size of the ventricle, but in general 0.75 ml per kg of body weight is a suitable quantity. The exposure of films begins simultaneously with the injection, 6 films per second being taken for 5 to 6 seconds. Views are taken in two planes at right angles to each other.

As has already been mentioned, selective catheterization and demonstration of the left ventricle does not seem to be a more dangerous procedure than thoracic aortography or catheterization and selective demonstration of the right ventricle, which methods are now regarded as risk-free except in cases with extremely grave myocardial lesions. The only part of the examination that might involve some risk is the manoeuvring of the catheter tip past the openings of the coronary arteries. If the technique now described is used, however, it is not likely that the catheter will penetrate into a coronary artery and remain there long enough to cause damage.

SUMMARY

The authors present the indications and describe the technique for catheterization nd selective roentgenographic demonstration of the left ventricle of the heart. The onditions in which these examinations should be used are: ventricular septal defect, trial septal defect involving the inferior portion of the septum, aortic valvular stenosis, ıbaortic stenosis, aortic valvular incompetence, mitral valvular disease, combined left eart valvular disease, and pathologic conditions of the ventricular wall.

ZUSAMMENFASSUNG

Die Verfasser geben einen Bericht über die Indikationen und die Technik der Katheterisierung sowie über die selektive röntgenologische Darstellung der linken Herzkammer. Die Zustände, bei denen die Untersuchungen benutzt werden sollten sind folgende: Ventrikelseptumdefekt, Vorhofseptumdefekt im unteren Teil des Septums, Aortenklappenstenose, subaortale Stenose, Aortenklappeninsuffizienz, Mitralisklappenerkrankung, kombinierte Klappenerkrankung der linken Herzseite und pathologische Zustände der Kammerwände.

RÉSUMÉ

Les auteurs exposent les indications et la technique du cathétérisme et de la radiographie sélective du ventricule gauche du cœur. Les affections dans lesquelles on devrait pratiquer ces examens sont: les communications septales interventriculaires, les communications septales interauriculaires intéressant la partie inférieure du septum, la sténose valvulaire aortique, la sténose sous-aortique, l'insuffisance valvulaire aortique, la maladie valvulaire mitrale, les affections valvulaires associées du cœur gauche et les affections de la paroi ventriculaire.

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THE POSTOPERATIVE MYELOGRAM

by

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Myelography after operation for herniated vertebral disc will not usually show any pathologic changes (KNUTSSON), but sometimes changes due to postoperative scarring may be seen (ARNELL, FRIBERG, KNUTSSON); these have been described as atypical irregularities at the operation level. According to LINDGREN, these alterations are situated more dorsally than those due to disc herniation. Any abnormalities in myelograms of patients who have undergone operation and been examined again for recurrent pain may thus be due either to disc herniation or postoperative scarring. The roentgenographic differentiation between these conditions is highly important.

Material. In an attempt to assess the possibilities of making a differential diagnosis, an analysis was made of lumbar myelograms of 34 patients who had previously undergone operation. The myelographic examination, which had been performed with a water-soluble contrast medium, had been undertaken because of recurrent pain following the operation. All the patients had been re-operated upon later.

Control material. For comparison we used 100 myelograms with pathologic changes which had subsequently been verified; in none of these

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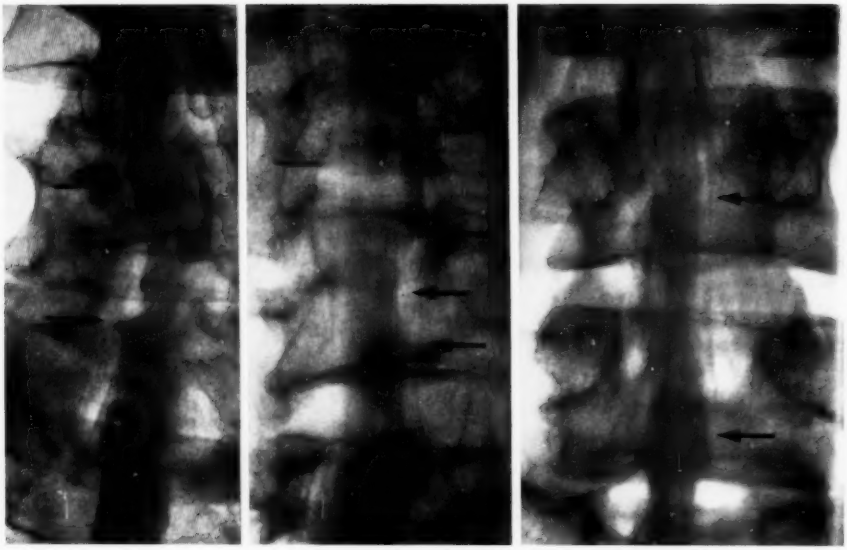
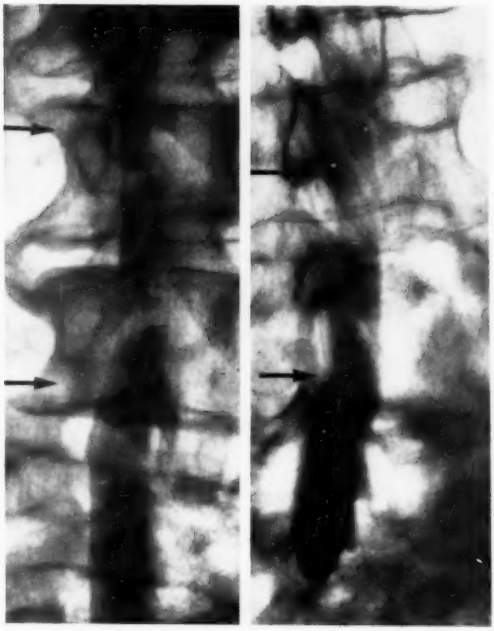


a b c

Fig. 1. a) and b) Postoperative deformations of irregular but sharply defined outline. The indentation is elongated and most evident at the level of a vertebral body. c) Deformation due to postoperative scarring and a herniated disc. Shallow and extremely elongated indentation somewhat more marked at level of disc.

cases had myelography been antedated by operation. The subsequent operation, which had been performed in the usual way, i. e. hemilaminectomy under local anaesthesia, had revealed disc lesions of varying degrees in all the cases. In a minor proportion of the cases the disc had only protruded, although in the majority it had more or less prolapsed, sometimes with sequestration and cranial or caudal displacement of the extruded disc material.

The myelograms of these 100 patients showed the typical defect in the filling of the subarachnoid space due to herniation of an intervertebral disc, i. e. a regular rounded indentation opposite to the disc involved, a varying degree of shortening of the dural sheath of a nerve root and in some cases definite thickening and frequent medial displacement of one or more of the ipsilateral nerve roots. In cases of midline protrusion of a disc the myelogram did not show any indentation of the dural sac in the a. p. projection but a local decrease in the density of the contrast medium at the level of the disc involved. The density was normal in the



a b

Fig. 2. Deformations due to spondylolisthesis (a) and to exostosis (b), most marked at the level of the vertebral bodies.

periphery but decreased towards the centre. One or more of the changes described above was seen in all the cases studied.

Disc protrusion cannot be differentiated myelographically from prolapse (DEL BUONO). But in 3 out of 7 cases with a sequestrated and displaced nucleus pulposus an evenly outlined defect was seen, not at the level of the disc but at the level of a vertebral body — thus between two nerve roots. Such a defect may sometimes be the only sign of a sequestrated disc (LINDGREN, DEL BUONO). In all the present cases, however, the myelogram also showed involvement of a nerve root or its dural sheath.

In 3 cases the flow of contrast medium was completely obstructed. Supplementary cisternal oxygen myelography was performed to determine the upper border of the obstruction. In all 3 cases the myelogram suggested a soft tissue swelling bulging into the anterior part of the spinal canal at the level of a disc.

Discussion of results

In 10 of the 34 re-operated cases operation revealed disc protrusion only, in 20 scar formation only, and in 4 both disc protrusion and scarring. Of the 10 patients with disc protrusion only, the myelogram showed changes of the types described above.

Of the second group, 20 cases with scar formation only, the myelograms were normal in appearance in 2, and in the remainder presented changes other than those of disc protrusion. The outline of the dural sac was thus sharply defined, irregular and sometimes dentate (See Fig. 1, a and b). In 2 cases the changes consisted of small irregular areas of decreased density in the contrast column. The defect was often most marked between ipsilateral roots, i. e. at the level of the vertebra. In about half the cases it involved a fairly long segment of the dural sac. In 1 case, for example, a shallow slightly irregular long narrowing was seen along a segment equivalent to the height of two vertebrae. In none of the cases examined was any root thickening observed, but the dural sheaths of the nerve roots were short in 10 cases. All cases showed one or more of the changes described above. In 1 case the flow of the contrast medium was completely obstructed and supplementary cisternal oxygen myelography revealed that the obstruction was due to a posterior soft tissue swelling bulging into and obstructing the dural sac at the level of the operated disc. The anterior outline of the dural sac was normal. Re-operation demonstrated that the obstruction was due to scar formation. As mentioned, the deformity caused by postoperative changes is said to be situated more posteriorly than that due to disc protrusion. This difference was striking in the last mentioned case, but less so in the others.

Scarring as well as disc protrusion were present in 4 cases. Two of these had been examined previously by myelography with iodized oil, residues of which were seen lying in the root sheaths. In one of the cases the flow of contrast medium was completely obstructed, while in the other the myelogram showed the typical rounded defect due to protrusion of an intervertebral disc. The same myelographic change was evident in the remaining 2 cases as well as a shallow irregular impression of the dural sac along a segment, corresponding to half the height of a vertebra below and above (Fig. 1 c).

Postoperative scarring thus usually appears in the myelogram as an irregular elongated defect, sharply defined, and situated between the nerve roots.

The reason why the postoperative change occurs so often between two nerve roots may be illustrated by a case, in which a woman, aged 44, was operated upon for lower back pain, radiating down the lateral aspect

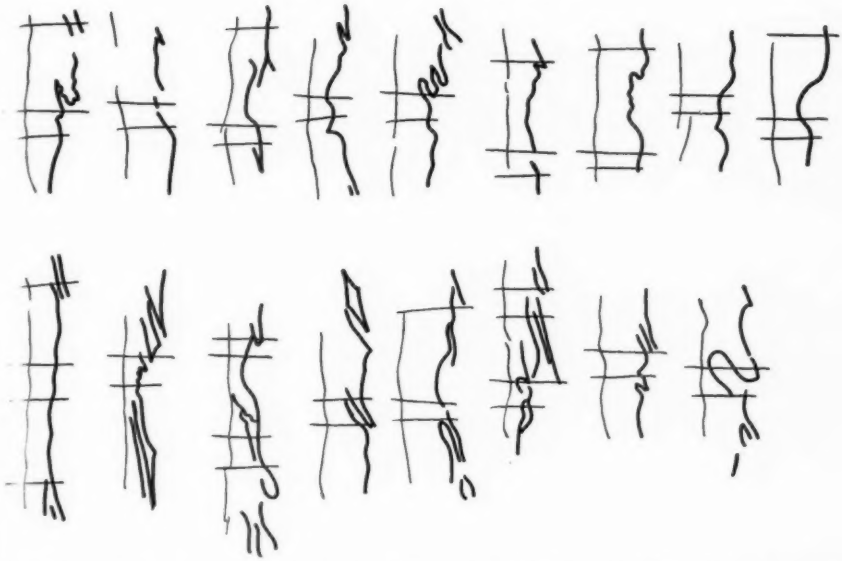


Fig. 3. Sketches for illustration of the site and appearance of the deformities, in myelograms from 17 re-operated patients with operative finding of scar tissue. Horisontal lines represent the borders of discs. All deformations are drawn as left-sided in order to facilitate comparison.

of the right leg. Operation revealed herniation of the disc between the fourth and fifth lumbar vertebrae. Two days later the pain recurred. Myelography 13 days after the operation showed a fairly long slightly irregular impression between 2 nerve roots at the level of the vertebral body, i. e. typical defect due to postoperative scarring. Re-operation revealed a haematoma. It seems that when postoperative bleeding occurs, the haematoma forms at the site of least resistance, i. e. where the dural sac is loosely attached, such as between the exits of the nerve roots. Such a haematoma may compress the nerve and cause pain, as in this case. It may also, however, organize and not cause pain until later, probably on the formation of fibrotic tissue.

Careful examination of a myelogram for the changes described above provides a possibility of differentiating between postoperative changes and recurrent disc herniation (See Fig. 3). To differentiate between such postoperative changes and disc sequestration is difficult. The site of the defect in the myelogram is the same as in scar formation. In all the 7 cases of this type in the present material, however, the filling defect was rounded and thereby differed from that of scar formation. In all

these 7 cases a root or its dural sheath was also involved. The possible coexistence of both a recurrent disc protrusion and scar formation offers particular difficulties in the differential diagnosis. In the cases referred to above, however, the myelogram showed not only a defect suggestive of scarring but also a short, rounded indentation opposite a disc.

If the flow of contrast medium is completely obstructed, it may not be possible to distinguish between a disc protrusion and an extradural or subarachnoidal space-occupying tumour. This also holds for total obstruction by scar formation.

Myelographic changes simulating postoperative scarring were seen in 4 unoperated patients. Of these, 3 had spondylolisthesis and the filling defect was due to distension of the dural sac caused by displacement of the vertebrae in relation to one another (Fig. 2a). In the fourth case the deformation was due to an exostosis localized to half the circumference of a vertebral arch (Fig. 2b). In all these cases roentgen examination of the spine revealed the changes responsible for the filling defect.

Conclusion. Pathologic changes in myelograms of patients operated upon for recurrent pain after previous operation may be due to recurrent disc protrusion or to postoperative changes. An irregular enlongated filling defect, most marked at the level of a vertebra, suggests that the change is postoperative.

SUMMARY

Changes in postoperative myelograms of 34 patients were compared with those seen in myelograms of 100 unoperated patients in whom subsequent operation revealed disc protrusion or prolapse. The myelographic findings in both groups are described. The presence of changes in myelograms obtained after operation suggests that they are due to postoperative scarring.

ZUSAMMENFASSUNG

Die Veränderungen in postoperativen Myelogrammen von 34 Patienten wurden mit den Befunden bei 100 präoperativ myelographierten Patienten, bei welchen die Operation eine Protrusion oder einen Prolaps der Zwischenwirbelscheiben zeigte, verglichen. Die myelographischen Befunde in beiden Gruppen werden beschrieben. Das Vorhandensein von Veränderungen in Myelogrammen, welche nach der Operation gemacht wurden, deutet an, dass sie durch postoperative Narbenbildung bedingt sind.

RÉSUMÉ

L'auteur a comparé les anomalies myélographiques post-opératoires de 34 malades a ec celles qu'il a trouvées sur les myélographies de 100 malades non opérés, chez qui une o ération ultérieure a montré des protrusions ou des hernies discales. Il décrit les signes n élographiques dans ces deux groupes de cas. L'existance d'images anormales sur les n élographies faites après opération fait penser qu'elles sont dues à la cicatrice post-o ératoire.

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THE RADIOPAQUE POLYTHENE CATHETER

by

Per Ödman

In the early days of intravascular catheterization (BLEICHRÖDER, FORSSMANN (1929), KLEIN, and others) and angiography (FORSSMANN (1931), ICHIKAWA, FARIÑAS, CHAVÉZ et coll., and others) only conventional ureteric catheters or soft rubber tubes were available; though roentgenopaque, these catheters were not specially adapted for intravascular use.

COURNAND et coll. were the first to describe the catheter now widely employed in examinations of the heart and large vessels. Cournand's catheter is made of polyvinyl chloride built up upon an inner framework of fabric; it would appear from roentgen crystallographic analysis that the roentgen ray absorption of the material is increased by the incorporation of comminuted ordinary tin. In Lehman's modification of Cournand's catheter the wall is thinner, but otherwise both models are identical. The Rüchelit catheter is also made of polyvinyl chloride, but it is thick-walled, has no fabric framework, and roentgen crystallographic analysis shows that it contains mercuric sulphide as an absorber. All of these catheters are supplied in standard lengths with fittings attached ready for use after sterilization. The examiner seldom adapts the instrument for any particular examination, though certain modifications are available, e. g. catheters with side holes, balloon catheters.

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Polythene tubing, on the other hand, is supplied in lengths of about m from which the examiner can make catheters of any desired ngth or shape. This material was first used in intravenous drip therapy (ALEXANDER et coll., DUFFY) and polythene catheters were soon used in angiography, where they proved suitable by reason of the thinness of their walls and their pliability (PEIRCE 1951, LINDGREN 1953, SELDINGER 1953). A disadvantage of ordinary polythene is, however, that it is not dense enough to permit fluoroscopic control of its passage through the vessels. Attempts have been made to overcome this disadvantage by the use of a guide wire, by filling the catheter with contrast medium (SELDINGER 1953, RODRÍGUEZ-ALVAREZ and MARTINEZ DE RODRÍGUEZ 1957), and by the application of a metal tip (GIDLUND 1956, LINDELL and OLIN 1957). The incorporation of a radiopaque substance in the polythene has also been tried. Roentgen opaque polythene tubing supplied by the American Cystoscopic Makers Inc. (ACMI), for example, was found on crystallographic analysis, to contain barium. This tubing does not appear to be sufficiently radiopaque for intravascular use. On the incorporation of a heavy metal salt, such as lead oxide, however, (ODMAN 1955) the polythene catheter will show up well on the fluoroscopic screen.

The incorporation of inorganic salts must be carefully adjusted, the addition of such material tending to make the tubing brittle and its surface rough, the latter favouring clot formation. This effect on the tubing varies in degree with the type of roentgenopaque substance employed and with the structure and size of the grains. Experiments with salts of heavy metals in varying proportions have made it possible to manufacture tubing satisfactory for intravascular use. Such tubing resembles conventional polythene tubing in consistence, surface smoothness, melting point, mouldability and ductility but it is so radiopaque that it can be identified even in the densest part of the body. This type of tubing is manufactured by AB Kifa, Stockholm, and is known as Kifa X-ray opaque catheter. It is available in 3 sizes:

Fine (red)	outer diameter	2.0	mm,	inner diameter	1.15	mm		
Medium (green)	»	»	2.4	»	»	»	1.3	»
Large (yellow)	»	»	2.85	»	»	»	1.5	»

The physical properties of the tubing are considered below.

The relative roentgen ray absorption of various catheters was determined by means of a roentgen tube fed with a stabilized direct current and without extra filtration. The tubing was placed in the path of a beam 0.2 mm by 10 mm in size and the intensity measured before and after insertion by means of a photomultiplier tube in an aluminium chamber with a fluorescent screen immediately before the photocathode.

Table

Catheter	kV	$\frac{I}{I_o}$	Wall thickness mm	d cm	μ	% absorption
Kifa, large	72	0.388	0.6	0.12	8.1	61
» medium	»	0.448	0.5	0.10	8.0	55
» fine	»	0.521	0.4	0.08	8.15	48
ACMI No. 8	»	0.725	0.4	0.08	4.0	27
Lehman Ch 9	»	0.398	0.6	0.12	7.9	60
Cournand Ch 9	»	0.279	0.8	0.16	8.0	70
Kifa, large	89	0.432	0.6	0.12	7.0	57
» medium	»	0.495	0.5	0.10	7.0	51
» fine	»	0.568	0.4	0.08	7.1	44
ACMI No. 8	»	0.751	0.4	0.08	3.5	24
Lehman Ch 9	»	0.435	0.6	0.12	6.9	56
Cournand Ch 9	»	0.327	0.8	0.16	7.0	67

The current indicated by the photomultiplier tube represented the relative intensity of the radiation. If I_o is the intensity of the incidental rays, I the intensity of the transmitted rays, and d twice the thickness of the wall of the catheter, the transmitted radiation may be expressed by the formula

$$I = I_o - e^{-\mu \cdot d}$$

where μ is the absorption value of the substance for the voltage used (see Table). The small difference between the values found for μ may be explained by a slight variation in the thickness of the wall.

It is clear from the table that the absorption values found for the different catheters were, broadly speaking, equal, with the exception of that for the ACMI polythene X-ray opaque catheter, which was about half that noted for the others. On increasing the voltage from 72 to 89 kV the absorption decreased by only about 12 % (from 8 to 7 and from 4 to 3.5).

In a description of certain selective catheterizations (BIERMAN et coll.) the recommendation is made that the end of the Cournand catheter should be bent before use. This type of catheter, however, tends to reassume its original shape and cannot be modelled by heating and cooling; in addition, conventional polyvinyl chloride catheters, but not Kifa's catheters, soften when brought to body temperature, as was confirmed by the following experiment.

Equal lengths of catheter tubing of different types were placed in a water bath at 37° C. One end of each catheter was fixed to the wall of the container; the catheters were almost straight and lay horizontally. In contrast to the Kifa catheter, which remained horizontal throughout the entire test (1 hour), the other catheters gradually bent and their free ends

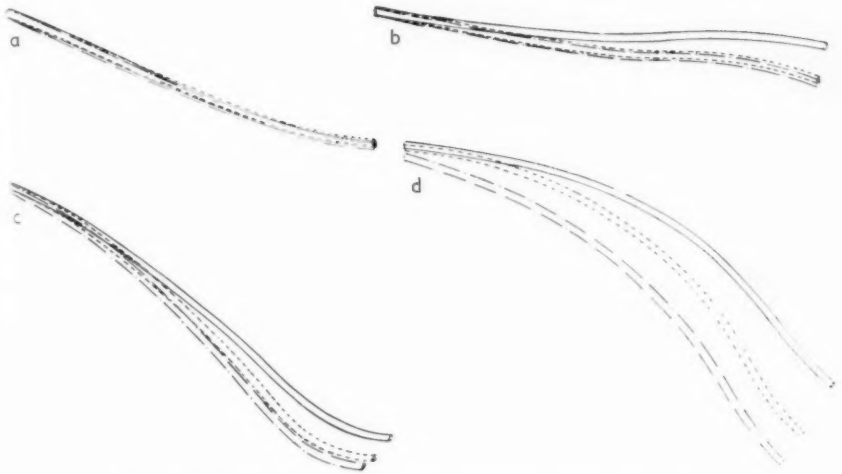


Fig. 1. Consistency of catheters at body temperature (water bath at 37° C):

	Min. after commencement of test
a) Kifa X-ray opaque polythene catheter 'Large'	20 and 60
b) Cournand catheter, 10 Charrière	20 » 60
c) Rüchelit catheter, 10 Charrière	20 » 60
d) Lehman catheter, 10 Charrière	10 » 20

sank in the bath (Fig. 1). As expected from clinical experience, Rüchelit and Lehman catheters softened quickest. In protracted examinations the polyvinyl chloride catheters are difficult to manipulate because they become limp (RODRÍGUEZ-ALVAREZ and MARTINEZ DE RODRÍGUEZ' catheters were not available at the time of the experiment, but since they are made of nylon (polyvinyl chloride), there is no reason to suppose that they would not have softened like the Cournand catheter).

The lumen of a polythene tubing need not be circular. A catheter with a clover-leaf-shaped cross-section, for example, is stiffer and therefore easier to manipulate than one with a round lumen, a fact which has proved valuable in the catheterization of the coeliac artery (ÖDMAN 1958). Furthermore, biluminal roentgen opaque polythene catheters have been used in the recording of pressure differences in the aorta; such determinations have also been made with Kifa's large size catheters introduced percutaneously via both femoral arteries until the tips of the catheters were at a desired distance apart in the aorta (PORJÉ and RUDEWALD).

A 54 cm length of Kifa tubing of large size was found to have

Fig. 2. Injection of contrast medium into left atrium by means of a polythene catheter with side holes. Interauricular septal defect (→ ←).

a constant amplitude at an undamped natural frequency response of 23 c/s, and a 50 cm piece of tubing of medium size (green) had a corresponding value of 17 c/s (HOLMGREN).

The wall of a radiopaque polythene tubing can be made relatively thin; the lumen of a prototype catheter of this material was found to be larger than that of a Cournand catheter, 12 Charrière, of the same outer diameter. Thus, the rate of flow through a 80 cm length of opaque tubing when tested with a Gidlund injector apparatus at a pre-set pressure of 5 kp/cm² was more than 100 ml/sec as against 40 ml/sec through the Cournand catheter. This type of catheter was tried in adults in examinations for interauricular septal defects by the method of BJÖRK et coll. It permitted a rate of injection enough to secure good definition of the defect (Fig. 2).

Kifa tubing was tested for any liberation of metal salts during catheterization. A strip of the material (10 cm by 1 mm by 1 mm), in which the absorber was tagged with the radioactive isotope RaD, was introduced into the abdominal aorta of a full grown rabbit and left there until the animal was killed 30 hours later. The kidneys, liver, spleen, intestines, stomach, bone tissue, urine, and intestinal contents were then examined for radioactivity by means of a Geiger-Müller counter capable of recording activity down to 2 micrograms of RaD. In none of the organs studied was any radioactivity demonstrated. As far as can be judged from this experiment, the roentgen opaque component is not liberated during catheterization.

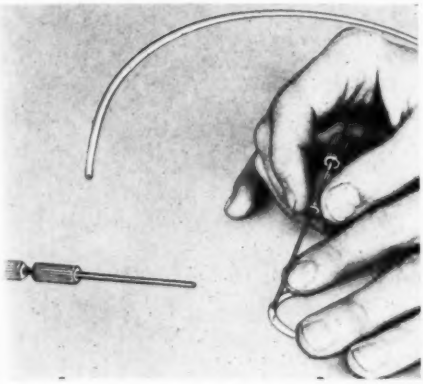
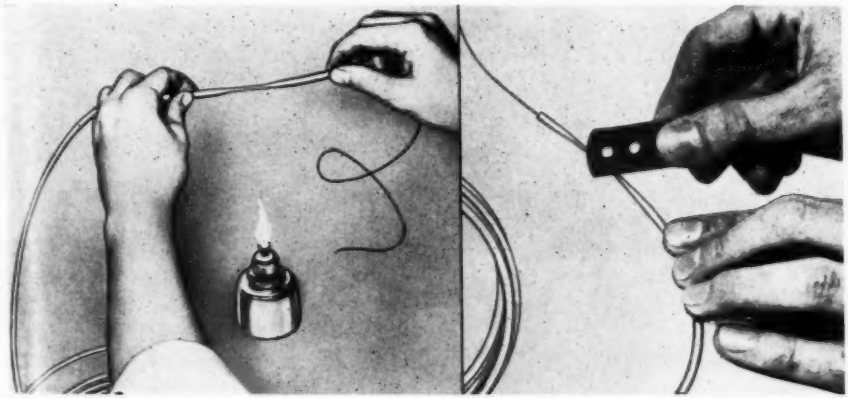


Fig. 3. Cutting side hole in Kifa tubing with a square-edged cannula.

Kifa tubing is supplied in 5 metre coils from which the examiner himself may prepare catheters for different purposes. The wall of the tubing is homogeneous and so soft that side holes can be cut out with a cannula with a squarebevelled end (Fig. 3). In other radiopaque catheters side holes cannot be cut in this way, but may be made with a hot needle or a dental burr; the edges of such perforations, especially in catheters built up on a fabric framework, are uneven and jagged.

The melting point of polythene is about 117° C. Heated to this temperature over a spirit flame, for example, Kifa tubing may be drawn out into a slowly tapering tip with a thin wall and a lumen just large enough to fit a nylon or metal guide (Fig. 4). This is not possible with a Cournand or Lehman catheter, which therefore cannot be used for percutaneous catheterization by Seldinger's method. The sealing of the distal end of a Cournand or Lehman catheter may be effected (e. g.



a b

Fig. 4. Preparing tip of Kifa tubing.

a) Catheter with guide wire is heated over a spirit flame, gently stretched and cooled under cold running water.

b) The waist is cut by rolling the catheter under slight pressure from a razor blade. Lumen of tip corresponds exactly to diameter of guide wire.

when a tip with side holes is to be used) by means of a wooden plug fastened with plastic rubber (NORDENSTRÖM). Kifa tubing can, however, be sealed simply by melting the end over a flame. The tubing may also be curved by heating it over a flame which, however, involves the risk of deforming the lumen in the curved portion. It is therefore advisable to utilize the plasticity of the material at a lower temperature. The end of the catheter may thus be permanently curved by placing it in hot water (above 75° C) until it becomes soft and then bending it into shape and cooling it under running cold water to restore its rigidity (Fig. 5). It is possible by this procedure to shape a polythene catheter according to the requirements of the vascular anatomy.

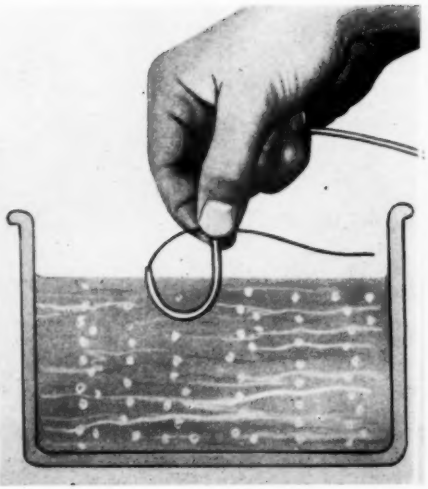


Fig. 5. Bending Kifa tubing. The tubing becomes plastic in hot water (above 75° C). Guide wire inserted. The curve is made permanent by cooling under cold running water.

The same conventional catheters are usually used in a series of cases, partly on the score of cost. This implies a risk of infection. Roentgen opaque polythene tubing is, however, so cheap that it need not be used more than once. The catheter should be sterilized in the same way as non-opaque polythene catheters.

Clinical use of radiopaque polythene tubing

For transfemoral percutaneous thoracic aortography a large size catheter should be used with the distal end bent and drawn out so that its lumen just fits a PE 160 size guide wire. Holes directed backwards are made just behind the tip; the purpose of these is to damp the recoil on injection and secure a more even distribution of the contrast medium (ÖDMAN 1956).

The same model is used for transfemoral percutaneous renal aortography but in this case it is shorter and its end is not bent. The catheter is fed up to the usual level of the renal arteries. By reason of the side holes the contrast medium does not spread so extensively into the aorta as on injection through a single terminal hole, when it may be squirted far up into the upper part of the abdominal and lower part of the thoracic

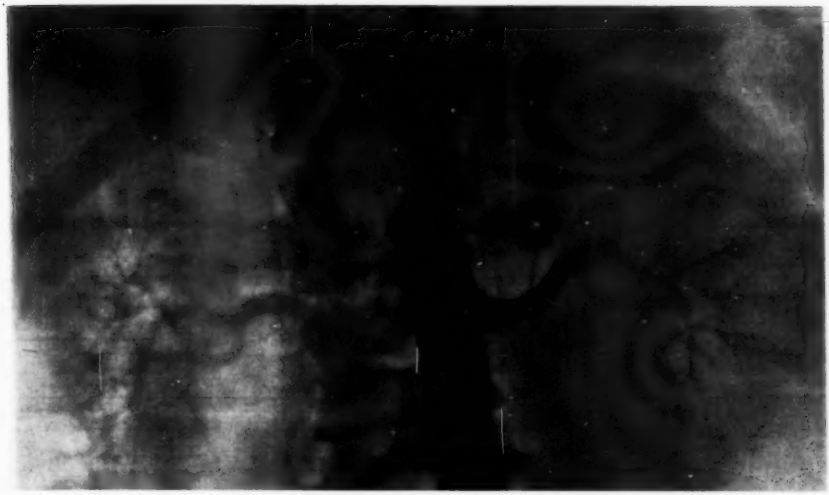


Fig. 6. Renal aortography with catheter with side holes. Filling of renal arteries but not of coeliac or superior mesenteric arteries.

aorta; the contrast medium will collect around the tip of the catheter so that a relatively large portion will pass into the renal arteries. This means that the dose of the contrast medium can be kept low. It also diminishes the risk of undesired filling of the coeliac and superior mesenteric arteries (Fig. 6).

If the pelvic vessels are too tortuous to permit passage of the catheter up the femoral artery to the abdominal aorta the catheter may be fed down into the aorta via the left brachial artery. For this purpose a 80 cm length catheter of medium size is used, the distal end being bent so that the tip may be fed from the subclavian artery down into the descending aorta (See SELDINGER 1957). The catheter is advanced to the level of the branches of the abdominal aorta to be studied; in this way the contrast medium may be discharged below the sensitive kidneys (Fig. 7).

The tubing has proved useful for percutaneous selective catheterization of branches of the large vessels, especially since the catheter can be moulded into any desired shape. The technique for these examinations has already been described (ÖDMAN 1956, 1958, 1959).

The following vessels may be catheterized:

A. Trunks from the aortic arch by transfemoral route. In these examinations the tip of the catheter may also be advanced further out into the more peripheral branches, such as the vertebral and subclavian arteries (ÖDMAN 1956).

B. The main branches of the abdominal aorta by the transfemoral or antegrade transbrachial route.

The former route is usually preferable because it permits the use of a shorter and larger catheter (ÖDMAN 1958, 1959).

C. Such arteries as the subclavian and axillary, the vertebral artery, the thyrocervical and costocervical trunks, and the subcapsular artery by the transbrachial route. Selective angiography of the internal mammary artery has been performed and will be described in another paper (ARNER et coll.).

D. The hypogastric artery via the ipso- or contralateral femoral artery. In the case of the ipsolateral femoral artery a fine Kifa catheter is used and the sharply bent end is passed up the common iliac artery. The catheter is then withdrawn slowly with the bent end directed against the mouth of the hypogastric artery (medio-posteriorly). The tip then usually glides into the lip of the mouth of the artery and occasionally it is possible to pass it a short distance out into the artery by gently advancing the catheter. In the case of the contralateral femoral artery a medium size catheter is used with a long distal curve. The tip is positioned just above the bifurcation of the aorta and the wire guide withdrawn so that the curved end will bend over the raphe at the bifurcation. The tip is then manipulated into the contralateral common iliac artery and the catheter gently advanced until it reaches the contralateral hypogastric artery. For the filling of this artery and its branches 15 ml Urografin 60 % are injected by hand. The presence of contrast medium in this vascular area causes a sensation of warmth in the gluteal region, the inner surface of the thigh, and the scrotum.

Fig. 7. Lower lumbar aortography by percutaneous catheterization via left brachial artery. Tip of catheter positioned below level of renal arteries.

E. Several of the branches of the inferior vena cava (hepatic and renal veins, hypogastric vein) may be approached by percutaneous catheterization via the femoral vein. A large size catheter with side holes directed towards the tip and with the end slightly bent are used, and 10 to 15 ml Urografin 60 % injected by hand. Readers interested in the examination of the hepatic veins are referred to HELANDER et coll.

Kifa catheters have also been tried successfully in bronchography in children (RUDHE) where they have proved successful especially as they can be shaped according to requirements.

Discussion

Perusal of the literature failed to reveal any critical appraisal of roentgenopaque catheters for intravascular use except in the investigations reported by RODRÍGUEZ-ALVAREZ and MARTINEZ DE RODRÍGUEZ. The examples described by them and in the present paper show that it is possible experimentally to test the essential properties of a catheter for angiography.

Most examiners seldom adapt a polyvinyl chloride catheter for a given purpose because of the relatively few possibilities of doing so. Roentgenopaque polythene tubing provides the means of making a special catheter for each type of examination and to a certain extent even for individual topographic needs. This has proved advantageous in the selective catheterization of branches of large vessels, particularly in angiography. An advantage of selective angiography over injection into the large vessels, usually the aorta, is that the branches to be studied are not masked by overlying contrast-filled vessels. The amount and concentration of the contrast medium may be adjusted according to circumstances. This permits improvement of the contrast density in certain vascular fields without exceeding the tolerance limit of the organs to the contrast medium.

The catheter should be such as to permit accurate manipulation into the desired position. The accuracy with which it can be positioned depends, above all, on two factors, namely its size and the distance it has to be passed; the larger the catheter and the shorter the path, the easier the positioning. A large catheter, and thus a large calibre, permits a high rate of injection, which is advantageous in the examination of arteries, especially large ones, such as the coeliac artery (ÖDMAN 1958).

Cournand's catheter cannot be used for retrograde catheterization of the branches of the abdominal aorta because it is not mouldable. BIERMAN et coll., TILLANDER, and MORINO et coll. catheterize visceral vessels by passing a Cournand catheter via an artery of the left arm but since only relatively small vessels are available for such insertion, only such

small sizes as 8—9 Charrière can be used; in these examinations the catheter must traverse a fairly long and partly tortuous path. In addition, the tip of the catheter has a tendency to pass into the ascending aorta instead of the descending aorta on its passage from the left subclavian artery into the aortic arch, because the end of the Cournand catheter is not bent. It is much easier to obtain selective filling of the branches under consideration with a roentgen opaque polythene catheter.

A further advantage of this type of catheter is that its tip may be fed into the mouths of several important arteries by the transbrachial route. A polyvinyl chloride or conventional polythene catheter has hitherto been tried for this purpose; the latter is introduced percutaneously. Neither on transfemoral (BIERMAN et coll., HELMWORTH et coll. LINDGREN 1956, and others) nor on transbrachial (RADNER 1949 and 1951, SELDINGER 1954) insertion can the tip of the catheter be manipulated with any degree of accuracy into the branches of the subclavian and axillary arteries; it has hitherto been possible to obtain selective filling only of the vertebral artery.

The hepatic and renal veins have also been catheterized with a Cournand catheter introduced via an arm vein (BRADLEY et coll., MYERS and TAYLOR, TORI). This technique has not been widely used in angiography, probably because of the long path to be traversed and of the difficulties in manipulating the catheter through the right atrium. The procedure is much simpler if performed by retrograde catheterization in the way described in this paper. GIDLUND has also catheterized the renal veins via the great saphenous vein with a polythene catheter provided with a manoeuverable tip.

SUMMARY

The properties of Kifa radiopaque tubing are described and discussed. Special attention is drawn to the value of the catheter in percutaneous selective angiographic methods.

ZUSAMMENFASSUNG

Die Eigenschaften des röntgendichten Kifa-Katheters werden beschrieben und diskutiert. Besondere Aufmerksamkeit wird auf den Wert des Kateters bei den perkutanen selektiven angiographischen Methoden gerichtet.

RÉSUMÉ

L'auteur décrit et examine les propriétés du cathéter radio-opaque Kifa. Il attire spécialement l'attention sur l'intérêt de ce cathéter pour les méthodes d'angiographie sélective percutanée.

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PHYSICAL ASPECTS OF ROENTGEN THERAPY USING WEDGE FILTERS

I. Some new copper wedges and their applications

by

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Wedge filters have been used in deep roentgen therapy for at least eighteen years. Their advantages in the treatment of certain types of lesion are well appreciated. Yet even in Great Britain, where the method originated and has largely been developed, it cannot be said that wedge techniques are widely used; in many other countries they appear to be almost unknown. Such apparent neglect of a proved therapeutic tool obviously warrants some explanation, and this neglect presumably derives from the difficulties associated with the use of wedge filters.

1. Good facilities for both construction and measurement are needed, since wedge filters are not available commercially, and special applicators may also need to be built.

2. It cannot be assumed that published designs and data are applicable to any but the specified radiation and geometrical conditions.

3. Even when wedge filters and isodose curves are available, their application in therapy — involving combined fields of two wedges and frequently also a non-wedge field — is likely to remain on a more-or-less ad hoc basis since the number of variables is large.

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4. In radical therapy the danger of untoward skin reactions along the 'hot edge' has to be guarded against.

In spite of these disadvantages, it has long been considered in the London Hospital that the wedge technique is a good one, offering as it does the possibility of raising to a uniform dose a volume of tissue situated near to the surface, by means of irradiation from one side only. This is done without the use of accurate beam-directing devices, and with relatively little irradiation of healthy tissue beyond the lesion. Indeed, it may be shown that, for lesions for which it is suited (e. g. larynx), the wedge technique at 250 kV gives rise to a smaller integral dose, for a given tumour dose, than any other technique using deep roentgen or radium teletherapy (including rotational therapy) and is equalled only by cross-fire techniques in super-voltage or kilocurie telecobalt therapy. (The latter may, of course, be further improved by the introduction of wedge filters.) It is well worthwhile, therefore, to try to minimise the ancillary conditions which must be fulfilled and to further strengthen the basis of wedge therapy: it is hoped that the present and subsequent work will contribute to this end.

Historical. Wedge filters for producing sloping isodose lines were first described by ELLIS and MILLER (1944), although FLOOD and SMITHERS (1939) had described filters to flatten isodose curves. Beam flattening filters were also described later by CHESTER and MEREDITH (1945). ELLIS and MILLER's wedges were originally of wood, later of laminated brass. The standard arrangement for therapy was a pair of wedges at right angles, often with a normal field aimed along the direction of the diagonal, but other arrangements were also tried. BUSH (1949) described the use of so-called 'harmonic' wedge filters in rotational roentgen therapy at conventional qualities. Unlike the wedges of ELLIS and MILLER, and nearly all subsequent wedge filters, BUSH's harmonic wedges were sloped right across the width of the field, instead of having a flat portion of filter at one or both sides.

Important developmental work was carried out at the London Hospital in the period 1947—1949, as described by ELLIS, SHANKS, OLIVER and KEMP (1950). The use of the KEMP automatic dose plotter (KEMP 1946) enabled the process of designing a wedge — which was, and to some extent remains, a matter of trial and error — to be greatly speeded up; furthermore the isodose curves could be plotted out more accurately and fully than hitherto. The London Hospital wedges consisted of brass strips built into the distal ends of special wooden applicators of shorter FSD (30 cm) than those normally employed. On the whole the disadvantages of this constructional method outweighed its advantages, and it has since been discarded at this and other hospitals.

The main feature of the work of ELLIS et coll. was the demonstration o the possibility of treating a variety of patients and lesions using a li ited number of standard arrangements of wedge and normal fields. T ese were: (1) two wedges at right angles, (2) two wedges and a normal fi ld in a hemi-hexagonal configuration, and (3) a pair of opposed wedges w h an intermediate normal field at right angles. In order to avoid a di ficult extrapolation to the surface along the central axis, the dose at a epth of 0.65 cm (the nearest point to the surface that could be measured) w s arbitrarily called 100 %. In this work the dose distribution, in co nbinations of wedge and normal fields, was depicted as an array of po nts (r/min) when the exposure time for each field was a stated number of minutes (usually 1 minute for the normal field and 1 or 1.5 minutes fo each wedge field), and the output of the set was specified.

HULBERT and GROOM (1950) described some wedge filters, modified fro m those of ELLIS et coll. designed to fit into the recess at the back of standard transparent-ended 'Fulfield' applicators of 50 cm FSD. These authors maintained that the increase in exposure time necessitated by working at 50 cm focal distance was immaterial compared with the advantages of using a standard applicator. Indeed, their wedges were easily removable from the applicator so that the latter could revert to normal use.

In a subsequent paper GROOM (1951) examined the effect on the isodose curves of alterations in the physical factors of copper wedges used with an incident beam of HVL about 1 mm of copper. He proposed simple rules for wedge construction to produce isodose curves of the same general shape and 45° slope, for any field size. It may be noted, however, that because of differences in specifying the slope of the isodose curves (see below) GROOM's 45° wedges would be regarded as somewhat steeper (about 52°) at the London Hospital. The maximum skin dose at the 'hot edge' is also considerably different from that associated with London Hospital wedges.

TOOZE and WORTHLEY (1954), also WORTHLEY, TOOZE, BROWN and FRY (1955), used the optical integrator of WHEATLEY (1951) to calculate the isodose curves of wedge filters based on those of ELLIS et coll. and of GROOM. The importance of this work is that the method could be used to deal with a wedge that had been masked down to a smaller area, e.g. an 8 × 10 cm wedge masked down to 8 × 6 cm (see below for terminology).

Recently, information has begun to appear on wedge filters for use with supervoltage radiation (TRANTER 1957, DAY and FARMER 1958, FRANÇOIS 1958). TULLEY (1956) has described some wedges for use with a 100-curie cobalt unit, while for kilocurie cobalt units wedge filters have been produced by JOHNS (1955) and by FLETCHER (1956). The wedge

filters designed for the Picker cobalt unit installed at the London Hospital will be the subject of a later publication by the author.

Terminology. Following ELLIS et coll. (1950) and HULBERT and GROOM (1950) the wedge direction is given first, e. g. 6 × 8 cm.

The slope of wedge isodose curves varies with depth, and its specification must therefore be an arbitrary one. GROOM (1951) defined the slope as the angle made to the central axis by the 50 % isodose line. This convention has not, however, been followed in the present work because it is felt that normal (non-wedge) isodose lines ought by definition to have zero, rather than 90°, slope, and that the stated wedge slope should increase as the steepness — i. e. divergence from the normal — of the isodoses increases. Neither have we adopted the 50 % isodose as the reference since it is considered that the slope at a given depth along the central axis is more fundamental, and furthermore depends on fewer variables, than the slope of a given line. In particular, considering a pair of contiguous wedges at right angles — the original and basic arrangement in wedge therapy — the region of interest is centred on a point lying on the central axis of each wedge at a depth equal to half the width of the wedge, e. g. 3 cm depth in the case of a 6 × 8 cm wedge. Accordingly, we have defined wedge slope in the following way: a point is taken on the central axis at a depth equal to half the field width in the wedge direction. Then the wedge slope is taken as the angle which an isodose line through this point makes with the applicator face, when produced to meet it. In practice a wedge slope so defined is larger than the slope defined by the 50 % isodose, e. g. 45° (our method) is equivalent to about 37° (GROOM's method); conversely, the 45° wedge of GROOM would be considered to have a slope of about 52° by our method.

A division of opinion exists as to which point to define as 100 % in a wedge isodose chart. Eliminating the use of a purely arbitrary point, as already mentioned in connection with ELLIS et coll. (1950), we are faced with a choice of either the central axis surface point or the point of maximum skin dose (opposite the thin side of the wedge). A number of authors, including HULBERT and GROOM (1950) have favoured the latter method, but in the present work the former point has been adopted. This has the advantage of preserving the same convention for normal and wedge fields, and of stressing the existence of a hot edge from the fact that the dose in this region is over 100 %.

Additional terminology for the addition of wedge and normal fields will be discussed in part II.

The construction of copper wedge filters. The copper wedges which form the basis of the present work were designed in the first instance for use with a Watson XTI therapy set, operating at 250 kV with 1 mm Cu +

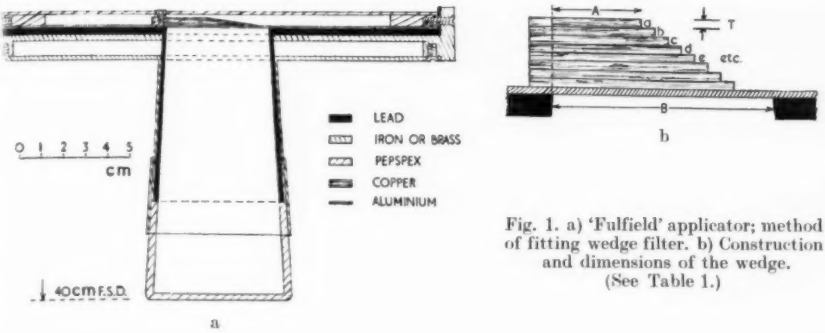

Fig. 1. a) 'Fulfield' applicator; method of fitting wedge filter. b) Construction and dimensions of the wedge. (See Table 1.)

1 mm Al clinical filter (HVL 1.74 mm Cu). This set was fitted with a master cone to accept 'Fulfield' type applicators. The standard 'Fulfield' series is of 50 cm FSD but a smaller 40 cm range is also available and these were chosen for the wedge applicators for the sake of a higher dose-rate. (OLIVER and KEMP have shown (1952) that the use of a shorter FSD does not materially affect the wedge isodose curves.) The 5 × 5 cm size was not, however, available and had to be specially constructed. The normal curved perspex ends of the applicators were replaced by flat ends, as flat-ended applicators are essential for wedge therapy which involves setting-up the applicator on the face of a wax jig.

Four wedge applicators have been found to satisfy nearly all demands in this hospital: 5 × 5 cm, 6 × 8 cm, 6 × 15 cm and 8 × 10 cm. Only rarely has the need for other sizes arisen, although a larger (10 cm) wedge would sometimes be useful. This cannot be constructed of the copper type, because of restrictions on maximum skin dose, but a 10 × 15 cm wedge of a new (graphite/tin) type has been built and will be described in part IV. The construction of the applicator and method of fixing the wedge are illustrated in Fig. 1, while in Table 1 data relating to the step sizes and thicknesses are given. (The Table includes two 8 × 10 cm wedges, for reasons explained below.)

The plotting of wedge isodose curves. The first designs for the wedges were based on an empirical analysis of the relationship between a wedge filter and its isodose curves, as revealed in the wedges in use in our hospital at that time (ELLIS et coll. 1950). The method will be described in full elsewhere. In view of the fact that the new wedges differed from the old in practically every factor, the agreement obtained between the measured isodose curves and those predicted was satisfactory, although some modification of the initial design was necessary in every case.

Table 1

Design data for copper wedge filters (Cf. Fig. 1b)

Step	Step width (A) and thickness (T) for sizes: 5 × 5 cm A (cm)	T (thou)*	6 × 8 cm A (cm)	T (thou)	6 × 15 cm A (cm)	T (thou)	8 × 10 cm (40°) A (cm)	T (thou)	8 × 10 cm (50°) A (cm)	T (thou)
a	1.0	6	1.5	8	1.5	10	2.0	6	1.75	8
b	1.2	6	1.75	8	1.75	10	2.25	6	2.0	8
c	1.4	6	2.0	8	2.0	10	2.5	6	2.25	8
d	1.6	6	2.25	12	2.25	12	2.75	6	2.5	8
e	1.8	6	2.5	12	2.5	12	3.0	6	2.75	8
f	2.0	6	2.75	12	2.75	12	3.25	10	3.0	10
g	2.2	12	3.0	12	3.0	12	3.5	10	3.25	14
h	2.4	12	3.25	12	3.25	12	3.75	10	3.5	14
i	2.6	12	3.5	12	3.5	12	4.0	10	3.75	15
j	2.8	12	3.75	12	3.75	12	4.25	10	4.0	15
k	3.0	6					4.5	10	4.25	15
l	3.2	6					4.75	10	4.5	15
m							5.0	10	4.75	15
n									5.0	15
Total wedge thickness (thou)		96		108		114		110		168
Aperture width (B) (cm)	3.75		4.5		4.5		6.0		6.0	

* 1 thou = 0.0254 mm.

The isodose curves were measured in a water phantom with a KEMP automatic-isodose-plotter (KEMP 1946). Three difficulties special to the plotting of wedge isodose curves may be mentioned:

1. The extrapolation along the central axis to obtain the surface reading (100 % point) is subject to a larger error than in the case of a normal field. The applicator has to be set up very carefully in relation to the water phantom to ensure accurate localization of the central axis. Even so, the accuracy of central axis percentage depth doses in wedge fields is lower than in ordinary work, and is probably not better than ± 3 %.

2. Owing to the hardening of the beam by the wedge filter, the range of wavelengths encountered within the phantom is larger than with normal fields. The response of the chamber must therefore be carefully checked to be independent of wavelength over a wide range. In the present work a small 'exploring' chamber was used, similar to that described by KEMP (1946) but having a cap of pure graphite (6 mm inside diameter) — thereby avoiding the anomalous effects sometimes associated with

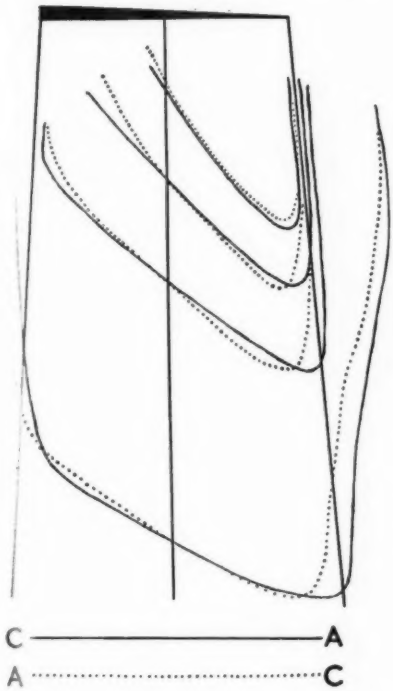

Fig. 2. Effect on wedge isodose lines of reversing the direction of the wedge relative to the anode-cathode axis of the tube. Full lines: thin end of wedge towards anode. Dotted lines: thin end of wedge towards cathode.

impurities in colloidal graphite (KEMP and BARBER 1956) — and an aluminium central electrode 0.070″ (1.8 mm) in diameter. The chamber response varied by only ± 1.1 % in the range HVL 2.5 mm Cu to 0.15 mm Cu.

3. The intensity of a roentgen beam is not symmetrical about the central axis in a plane containing the anode-cathode axis of the tube. The exact shape of the intensity curve varies from set to set and depends (FARR 1955) on the relationship between the 'emission effect' (the predominantly forward emission of roentgen rays generated in the target) and the 'heel effect' (the self-absorption of roentgen rays by the target). Although the asymmetry is most serious for large fields, in many sets the effect is quite noticeable even for small fields, and results in lopsided isodose curves which depend on the orientation of the applicator with respect to the tube. In the case of a normal field the effect can be allowed for by averaging the measured curves in the two halves of the field, the final set of symmetrical curves being accurate enough for clinical purposes.

In a wedge field, the beam asymmetry results in a change of isodose shape with orientation of the applicator. The two extremes, with the wedge direction parallel to the anode-cathode axis, are illustrated in Fig. 2. Averaging is only possible if each set of curves is measured twice. One solution is to insert the applicator with a constant orientation to the tube axis, but this may not be practicable in a busy department, especially if the master cone is freely rotatable round the beam axis. The solution we have adopted is to measure the isodoses with the wedge direction at right angles to the anode-cathode axis, by setting the axis of the roentgen tube vertical and plotting in a horizontal plane. Isodose curves measured in this way are found to be mid-way between those

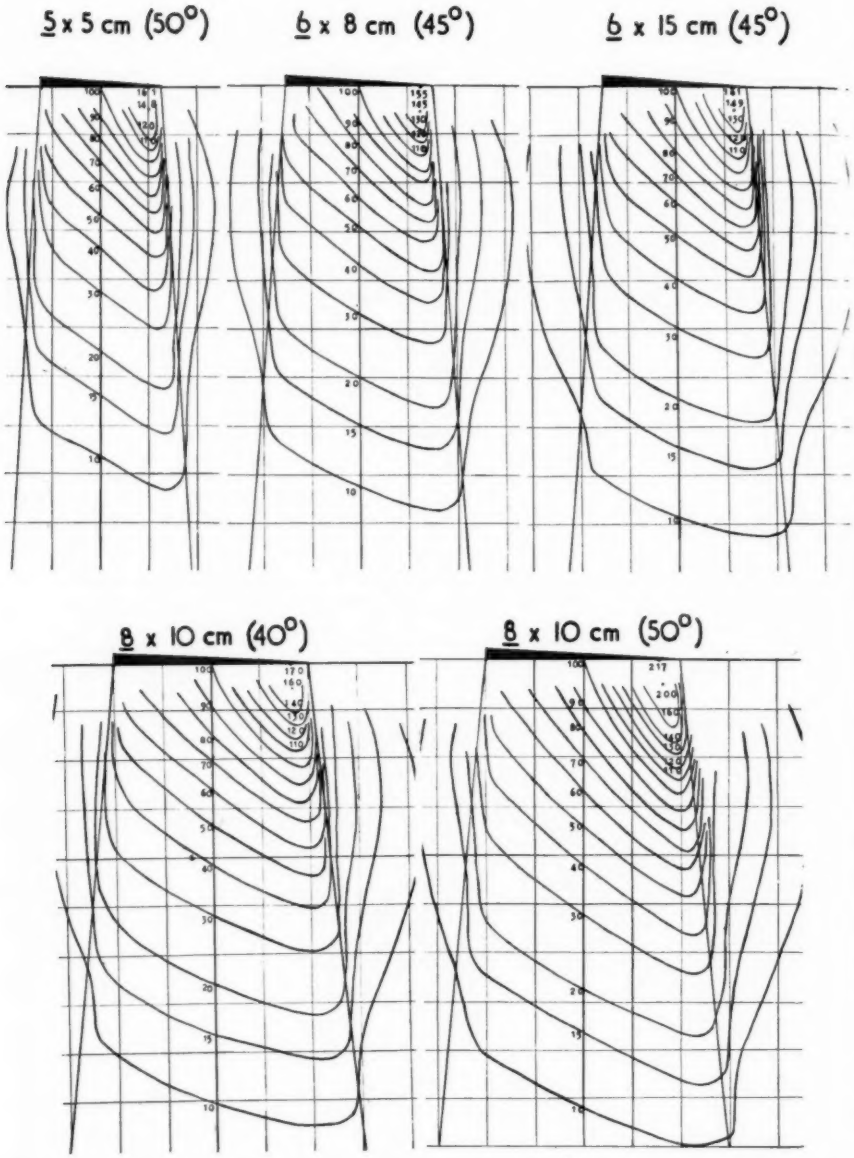

Fig. 3. Isodose curves of wedge applicators listed in Table 1. Figures in parenthesis indicate wedge isodose slope (see text). The grid is divided into 2 cm squares.

own in Fig. 2 and thus provide average curves in a single measurement. o attempt is made to regulate the orientation of the wedge vis-a-vis e tube during treatment.

The maximum surface dose. The maximum surface dose, opposite t e thin edge of the wedge, is an important factor in wedge therapy, a hough it has received surprisingly little attention in the literature. l gives rise to an enhanced skin reaction along the 'hot' edge, which r ist not be allowed to become too severe if permanent damage is to b avoided. In this hospital it is considered that, for radical therapy i volving tumour doses of 4 000—5 000 r in four weeks (depending on s e and size) the maximum skin dose must not exceed 150 % of the t nour dose and should preferably be less, say 130 to 140 %. This provides a practical limit both to the design of a wedge and to the way it is combined with other fields to form actual treatment arrangements. The la ter question is discussed in part II of this paper; the former entails a limit of 160 to 170 % in the 'hot edge' dose of an individual wedge. (Although the high dose region actually comprises a line or narrow band in the non-wedge direction of the field, when only a single plane is considered, i. e. the central plane containing the wedge direction, the line becomes a point. For this reason, the hot edge is more commonly referred to as the 'hot-spot', leading to the concept of 'hot-spot factor' which will be developed in part II.) This limit is regarded as inviolate at the London Hospital, although it must be added that authors from other centres have described wedges, without adverse comment, in which the hot edge doses are considerably higher.

The limitation of the hot edge dose implies a limit to the steepness of the isodose curves for a given wedge size. Although it is often assumed that the ideal wedge should have isodose lines of uniform 45° slope, this is strictly true only when the wedge is intended to be used in a contiguous-pair arrangement at 90°. In general, however, other arrangements and also a third (normal) field will be used, and it will be shown in part II that for each wedge size there is an optimum wedge slope which gives the best results for a large number of configurations.

The analysis to be described in part II was, of course, carried out after the production of the present wedges, and the guiding principles during the design stage were somewhat simpler than the concept of optimum slope. The principles were that, other factors being equal, steep isodose lines are advantageous; but the steeper the isodoses the greater the hot edge dose necessarily becomes, and, for isodose lines of a given slope, the hot edge dose increases as the wedge becomes wider. Thus, instead of stipulating in advance that each wedge should have a slope of 45°, the problem was approached from the other end: each wedge

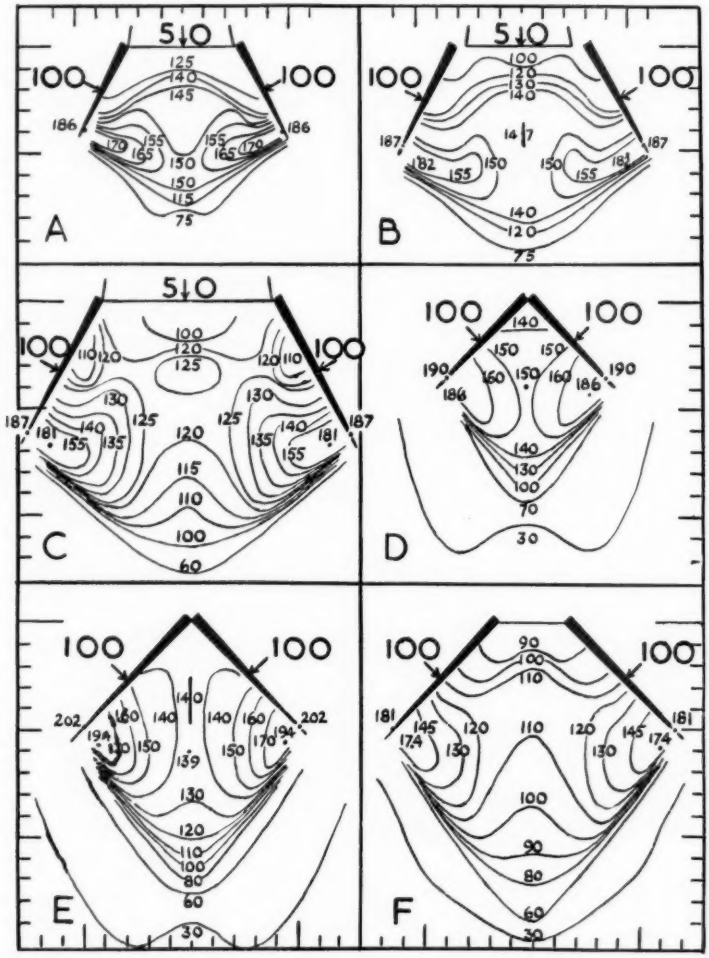

Fig. 4. Examples of dose distributions for two- and three-field wedge arrangements. The scale divisions are centimetres.

A) 5 × 5 cm wedge pair (100 r each) at 60°, 5 cm separation, plus 5 × 5 cm normal field (50 r).
B) 6 × 15 cm wedge pair (100 r each) at 60°, 6 cm separation, plus 15 × 5 cm normal field (50 r).
C) 8 × 10 cm wedge pair (100 r each) at 60°, 8 cm separation, plus 10 × 8 cm normal field (50 r).
D) 6 × 8 cm contiguous wedge pair at right angles.
E) 8 × 10 cm contiguous wedge pair at right angles.
F) As (E), but with 3 cm separation.

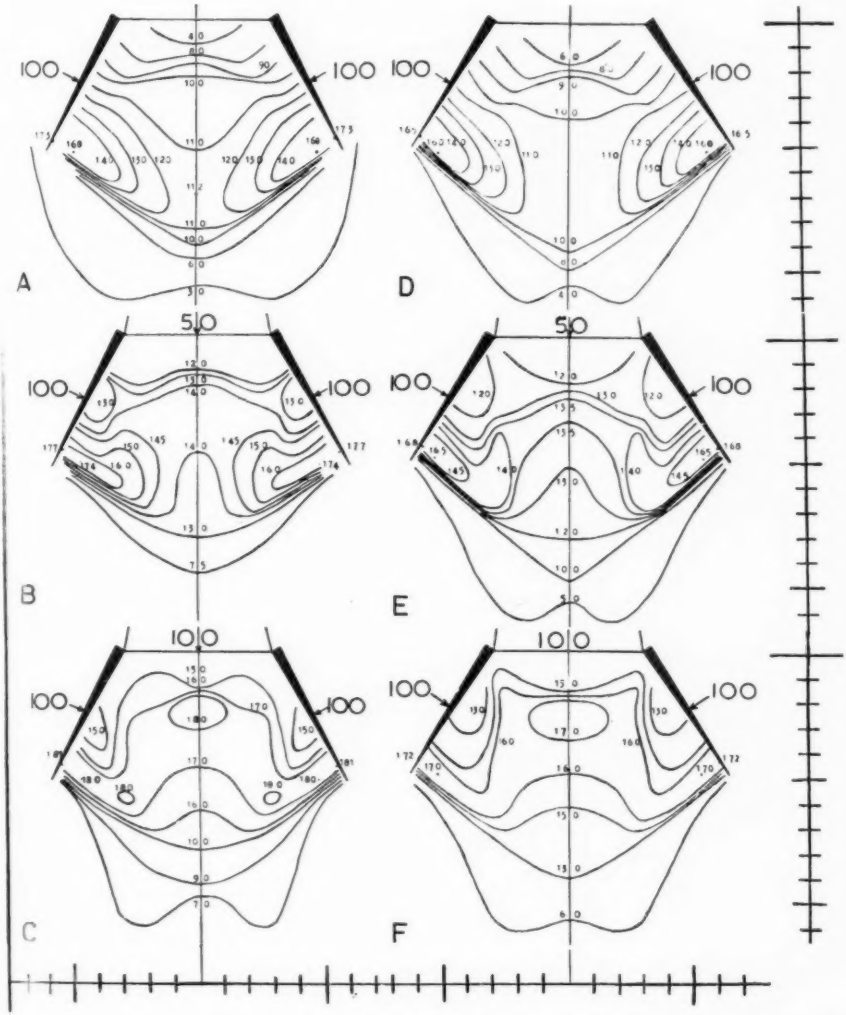

Fig. 5. Development of the three-field technique. 6 × 8 cm wedge pairs (100 r each), 6 cm separation plus 8 × 6 cm normal field. The scale divisions are centimetres.

A) Wedges at 60°, normal field dose = 0.
B) Wedges at 60°, normal field dose = 50 r.
C) Wedges at 60°, normal field dose = 100 r.
D) Wedges at 70°, normal field dose = 0.
E) Wedges at 70°, normal field dose = 50 r.
F) Wedges at 70°, normal field dose = 100 r.

Table 2

Surface dose-rates with wedge applicators

Field size	Surface dose-rate factor of wedge	Typical surface dose-rate [1] (r/min) Wedge applicator	Normal applicator
5 × 5 cm	4.09	34.8	44.5
6 × 8 cm	4.30	36.5	48.0
6 × 15 cm	4.47	38.0	50.3
8 × 10 cm	4.46	37.9	51.2

[1] Based on a 'standard output' of 8.5 r/minute.

could be as steep as possible without transgressing the 170 % limit for hot edge dose. The wedges so produced are now considered to be fairly close to optimum, although room remains for further improvement.

The isodose curves of the five wedges detailed in Table 1 are shown in Fig. 3. Only the two 6 cm wedges have 45° slopes; the 5 cm wedge has been given a slope of 50° with a hot edge dose of 161 %, while the 8 cm wedge is necessarily shallower (40°). The last wedge is a preliminary version of the 8 × 10 cm, which was produced and plotted out in full, although in fact it was clinically unacceptable (hot edge dose = 217 %) and has never been used in therapy. It is included in the present series because it has proved useful, in the analysis described in part II, for studying the effect of wedge isodose slope. The slope of this wedge is 50°.

It follows from the above that the present series of copper wedges cannot be extended beyond 8 cm unless shallow isodoses (less than 40°) are accepted. In practice this has not been done, and the 10 × 15 cm wedge used in the London Hospital is of a different (graphite/tin) type, to be described in part IV. Another method of decreasing the hot edge dose will be discussed in part II.

Absolute dose-rates. In conformity with the London Hospital practice for ordinary fields (Oliver and Kemp 1949, Cohen 1955), the absolute surface dose-rate of a wedge field is expressed in terms of a surface dose-rate factor (S. D. R. F.) defined thus:

$$\text{S. D. R. F.} = \frac{\text{Central axis dose-rate at the field surface with full back-scatter}}{\text{dose-rate in air at 100 cm measured with a standard (10 × 8 cm) applicator}}$$

The S. D. R. F. is measured by comparing the dose-rates at a convenient point in the water phantom, at which the percentage depth dose is known, with that in air at the point used for the regular output checks. In the latter case the applicator is, of course, a non-wedge type. The surface dose-rate (r/minute) for the wedge is obtained simply by

Fig. 6. Three-field wedge technique with Fulfield applicators for irradiation of the larynx.

multiplying the output obtaining at a particular time by the S. D. R. F. Table 2 lists the S. D. R. F.'s of the four copper wedges described (omitting the steep 8 × 10 cm), together with typical values of r/minute when the wedges are used on a Watson XTI set. The corresponding surface dose-rates of non-wedge applicators (50 cm FSD) of similar size are included for comparison.

Combined wedge fields. Examples of isodose charts prepared for clinical use are given in Figs. 4 and 5. In each case the incident dose for each wedge field is taken as 100, and that for the normal field, if any, as a suitable sub-multiple of 100. The normal field is an ordinary 50 cm FSD applicator which replaces the wedge applicator without change of kV or clinical filter. The normal applicator is chosen so that its dimension in the plane perpendicular to that of the isodose chart corresponds with the non-wedge dimension of the wedge applicator.

Treatment is carried out through a wax jig constructed for the individual patient, as described previously by Ellis et coll. (1950). A single photograph (Fig. 6) will suffice to link up the technique described in that paper with the Fulfield wedge applicators used at present.

The two basic arrangements are the contiguous pair at right-angles (Fig. 4, D and E) and the three field, hemi-hexagonal, configuration (Fig. 4, A, B, and C). The right-angled arrangement may be extended by leaving a gap at the apex, but there is a strict limit to the extent of this gap if the maximum skin dose is to be kept within safe limits. The 3 cm gap shown in Fig. 4 F is, in fact, a little beyond the limit of that permissible

for radical therapy. Larger gaps entail the use of smaller angles than 90° between the wedge fields, and the addition of a third field.

Fig. 5 illustrates the development of the 3-field technique. All charts refer to the 6 × 8 cm wedge. In (A) the two wedges are placed in hemi-hexagonal configuration, i. e. at 60° with a 6 cm gap at the apex. In (B) a normal 8 × 6 cm field is added, the normal field incident dose being 50 if the incident dose for each wedge field is taken as 100. In (C) the normal field incident dose is increased to 100. The process is repeated in (D) to (F), except that the angle between the wedges is increased to 70°. The extra 10° is extremely useful in many cases. It may be seen that from the point of view of the dose distribution in the tumour region — i. e. the production of a large volume of uniform dosage, conveniently sited in relation to the surface, followed by a rapid fall-off — the 2-field arrangements, (A) and (D), are undoubtedly best. The 3-field, equidose arrangements (C) and (E) are worst. Unfortunately, the maximum skin dose (in relation to the tumour dose), with its associated 'tongue' of high dose, runs in the opposite direction. In most cases the best compromise between tumour dose and skin dose is obtained with a normal field incident dose 25 to 50 % that of the wedge incident dose. The 50 % level is chosen for charting purposes because the preparation of combined field isodose charts is easier for this incident-dose ratio than for any other (except, of course, equi-dose arrangements).

The method of opposed wedges, described in some detail by ELLIS et coll. (1950) has been largely superseded by techniques involving inclined wedges, as illustrated in Figs. 3 and 4, for the sake of a lower skin dose, although some isodose charts of opposed arrangements have been prepared for the 5 × 5 cm wedge.

Over 30 isodose charts for combined fields involving the four wedges have been prepared, and the majority of patients can be treated with one or other of these arrangements. (Copies of these charts may be obtained through the Diagrams and Data Scheme (Hon. Secretary: C. GREGORY) of the Hospital Physicists' Association, at Mount Vernon Hospital, Northwood, Middlesex.) Those lesions which cannot be fitted to one of the standard arrangements may be treated by an ad hoc combination of fields, or, better, by the use of the dosage charts to be described in part II.

Acknowledgements

The author wishes to pay tribute to the late Dr. Geoffrey Boden, in whose department this work was carried out; his advice and encouragement were often sought and always forthcoming. Thanks are also due to Dr. L. A. W. Kemp for many valuable discussions.

SUMMARY

Wedge fields are ideally suited to the treatment of many lesions near to the body surface, but there are certain difficulties associated with their use and so far the method has not been widely adopted. These difficulties may, however, be minimized. The literature and terminology of wedge filters are briefly reviewed. New copper wedge filters are described. Some difficulties peculiar to the plotting of wedge isodose curves are mentioned. Examples are presented of combined wedge and normal field dose distributions, and the development of the three-field technique is illustrated, with special reference to the maximum skin dose.

ZUSAMMENFASSUNG

Keilfilter sind ausgezeichnet geeignet für die Behandlung von vielen Läsionen in der Nähe der Körperoberfläche. Da aber gewisse Schwierigkeiten mit ihrem Gebrauch verbunden sind, werden sie nicht oft angewendet. Diese Schwierigkeiten können jedoch weitgehend vermieden werden. Es wird eine kurze Übersicht der Literatur und Terminologie der Keilfilter gegeben, und neue Kupferkeilfilter beschrieben. Einige Schwierigkeiten bei der Festlegung der Isodosen von Keilfiltern werden angegeben. Beispiele für Keilfilter-Normalfilterkombinationen werden diskutiert und eine Drei-Feld-Technik ist beschrieben, wobei besonderes Gewicht auf die maximale Hautdosis gelegt wird.

RÉSUMÉ

Les filtres en coin conviennent en principe au traitement de beaucoup de lésions proches de la surface du corps, mais leur utilisation entraîne certaines difficultés et, jusqu'à maintenant, cette méthode n'a pas été largement utilisée. On peut cependant réduire ces difficultés. L'auteur rappelle brièvement la littérature et la terminologie concernant les filtres en coin. Il décrit de nouveaux filtres en coin en cuivre et signale quelques difficultés particulières dans l'établissement de courbes isodoses pour les filtres en coin. Il donne des exemples de distributions de doses par une association de champs normaux et avec coin et montre la mise au point d'une technique à trois champs, avec étude particulière de la dose maxima à la peau.

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TREATMENT OF PERITONEAL CARCINOSIS WITH COLLOIDAL Au^{198} IN COMBINATION WITH POLYPHLORETIN PHOSPHATE

by

Bengt Fries, Hans-Ludvig Kottmeier
and *Gunnar Walinder*

In a preceding paper (6) it was shown experimentally that the liver uptake following the intra-peritoneal injection of radioactive colloidal gold into mice and rabbits could be appreciably retarded if the animal had been given local treatment with polyphloretin phosphate (PPP) 24 hours previously. This substance, which is a synthetic polyphenol of high molecular weight (about 15 000), reduces the peritoneal permeability when administered intraperitoneally to rabbits; hence the prerequisites are at hand for achieving the afore-mentioned reduction in the liver uptake of a gold solution. From the clinical aspect of intraperitoneal gold therapy this retarded peritoneal permeability has two important advantages, viz. the isotope remains longer in the peritoneum, where the radiation is to take place, and the uptake in the reticulo-endothelial system (RES) decreases, an effect advantageous from the viewpoint of radiation damage.

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As a complement of these investigations in animals a number o other factors must, however, be considered in order to obtain the bes possible effect from PPP in connection with the clinical use of Au^{198}

The question as to whether PPP may be used intraperitoneally withou risk of side-effects has already been investigated by exhaustive toxicit determinations, which all showed that the toxicity of the substanc both acute and chronic, is very low. The LD^{50} for the mouse and the ra following intraperitoneal injection is 600 mg/kg of body weight. Poly phloretin phosphate has been in use for a few years in a number of clinic as a prophylactic against adhesions, and has been administered intra peritoneally in doses of 500 to 1 000 mg without causing side effects.

The dosage of PPP required to obtain in man the same effect as tha observed in rabbits and mice has also been investigated. In the afore mentioned experiments, rabbits weighing 2.5 kg were given 100 mg. and mice weighing 25 g received 5 mg of the substance; these amounts, recalculated for kilograms of body weight, are higher than the doses hitherto given in the clinics. In order to gain an idea of how the PPP dose affects the permeability, a series of experiments has been carried out on mice using different amounts of PPP intraperitoneally 24 hours before an injection of gold. The animals were killed 3 hours following the latter and the radioactivity of the liver was measured.

The time prior to the administration of the gold at which the PPP should be given in order to achieve the best effect must be known. In earlier studies on retarded peritoneal permeability PPP was given 24 hours before the injection of Au^{198}, but no investigations have as yet been made with a view to studying other intervals. An experiment was performed to determine the time which should elapse between the PPP administration and the gold injection in order to obtain maximum retarding effect. Mice weighing 25 g were given 5 mg of PPP intraperitoneally at different intervals before the injection of gold. The animals were killed 3 hours after the gold had been administered and the liver activity was measured.

The question as to whether the results previously obtained in animals may be applied to clinical material is of vital importance, and it is obvious that healthy experimental animals and human subjects with carcinosis of the peritoneum and ascites may show differences in the permeability of the peritoneum. It may be said that in principle there is no great difference in the peritoneal permeability to colloidal solutions between various mammals. Numerous experimental investigations (2) have demonstrated that animals such as mice, rats, rabbits, guinea-pigs and dogs do not show appreciable variations as regards the peritoneal penetration which, where colloidal solutions are concerned, mainly takes place through the lymphatics, and particularly via the cordiform tendon of the dia-

ragm (4). The same conditions apply in man. As stated before, the investigations mentioned were carried out in healthy animals whose peritoneal permeating capacity was presumably normal. The situation is different in a human subject with carcinosis of the peritoneum and associated ascites. It is mainly to combat this exudation that isotope therapy is applied, since the presence of large amounts of fluid in the abdominal cavity produces severe symptoms. Earlier studies of the penetration of radioisotopes from the abdominal cavity to the blood in the presence of a peritoneal effusion (5) have shown that this is considerably retarded and in some cases entirely inhibited. Hence, there is some reason for assuming that a human subject with ascites has retarded peritoneal permeability. This must be regarded as an advantage in as much as it ought to involve a slower passage of the gold and consequently a decrease in the liver uptake. In order to form some idea of how the presence of varying amounts of ascitic fluid affects the passage of colloidal Au^{198} injected intraperitoneally we endeavoured to reproduce the clinical conditions as nearly as possible in mice. Blood-free ascitic fluid was taken from mice with Lanschütz ascites, diluted ten times with Krebs-Ringer solution, and 0.2 ml of the preparation injected into the peritoneum of mice weighing 25 g. After incubation for one week all the mice showed enlargement of the abdomen due to ascites. Laparocentesis was performed and from 2 to 12 ml of fluid were drained off. One-half of the animals were given 5 mg of PPP intraperitoneally on this occasion. The others served as controls. Twenty-four hours later, all the animals received Au^{198} by intraperitoneal injection; they were killed 3 hours later, and the ascitic fluid in the abdominal cavity was carefully measured and the liver activities determined.

When human subjects with peritoneal carcinosis are given intraperitoneal gold treatment the injection is usually preceded by laparocentesis. To achieve good distribution in the abdominal cavity the injection of the gold is followed by a saline rinse, and in addition the patient is instructed to change his position repeatedly during the hours immediately following the injection so as further to facilitate the spread of the isotope solution in the abdomen. The spreading process can be observed over the entire abdominal field by scintography. This was done in all cases in the present investigation. The PPP-treated patients were given 1 000 mg of PPP in saline intraperitoneally following the laparocentesis, and the gold was injected 24 hours later. The controls on the other hand were given the gold injection in direct connection with the laparocentesis. The course of the permeation was followed in blood samples obtained 2, 4, 6, 12 and 24 hours after injection of the Au^{198}. Liver punctates were taken in most of the cases at the last-mentioned interval (S. Franzén, Radiumhemmet), efforts being made to obtain samples from a central part of the liver so as to avoid contamination by the gold from the surface of the liver. The liver samples were washed, weighed, and treated with aqua regia. The activity of the liver solutions thus obtained, as well as the blood samples, were measured in a well-type scintillation counter. The values were compared with standard solutions prepared from the gold colloid used for the original injections.

Results

Animal experiments

The part played by the PPP dose in lowering the permeability. After a preliminary dose of different amounts of PPP in mice the liver activity rose with decreasing amounts of the substance (Table 1). However, the activity did not increase by more than 25 per cent if the dose of PPP was reduced from 5 to 0.625 mg per animal. This smallest PPP dose would correspond to 1 250 mg per 50 kg of body weight, i. e. it is approximately the size of the dose given to prevent adhesions in clinical material.

Table 1

Liver activity in mice 3 hours after intraperitoneal injection of colloidal gold and 27 hours after different doses of PPP. Each group comprises 5 animals

Activity per liver Counts/min	Activity of total inj. gold per animal Counts/min	PPP 24 hrs prior to gold injection mg
2 050	24 790	5
2 400	24 790	2.5
2 410	24 790	1.25
2 570	24 790	0.625
4 740	24 790	0

The most suitable time for the preliminary dose of PPP. In the animal experiments (Table 2), the maximum effect was obtained when PPP was given 14 hours before injection of the gold. When the substance was administered 24 hours before the Au^{198} the liver activity showed only an insignificant rise. Shorter intervals of from 3 to 6 hours, gave a much poorer result.

Table 2

Effect of PPP on permeability of peritoneal wall. PPP given at different intervals prior to injection of gold. Each group comprises 6 animals. Animals killed 3 hours after gold injection

Group	PPP prior to gold injection hrs	Liver activity of total amount injected %
1	24	1.2
2	14	1.0
3	6	2.6
4	3	3.6
5	Control	3.3

Permeability to Au^{198} in ascites. It was clear from these experiments that the passage from the abdominal cavity was retarded in proportion to the amount of ascitic fluid remaining in the abdomen (Table 3). If large amounts of fluid still remained the permeation was equally slow whether the animal had been treated with a preliminary dose of PPP or not. The difference in permeability between controls and PPP-treated animals could be seen only if the amount of fluid present was small.

Table 3

Liver activity in mice with Lanshütz ascites 3 hours after intraperitoneal injection of gold

Number of animals	Activity per liver Counts/min	Activity of total inj. gold per animal Counts/min	Ascites ml	5 mg of PPP 24 hrs prior to gold injection
4	919	24 790	4.5—5.5	+
4	902	24 790	7 —8	+
1	524	24 790	13	+
3	4 640	24 790	0 —1	—
1	2 480	24 790	2	—
6	1 551	24 790	6 —7	—
2	945	24 790	7.5—8	—
1	499	24 790	14	—

Clinical material

Table 4 shows the case material. Two of the patients had received PPP 24 hours prior to injection of the gold, the dose being 1 000 mg in saline. PPP was injected in connection with laparocentesis; this procedure was carried out in every case except Case VII. It will be seen that there was no difference between the controls and the PPP-treated patients as regards the quantitative liver uptake.

Discussion

Clinical viewpoints. The result of the clinical investigation into the effect exerted by polyphloretin phosphate on the permeability of the peritoneal wall was largely negative, inasmuch as carcinosis of the peritoneum with ascites per se exercised an inhibitory effect on the permeability; this may be attributed among other things to the presence of ascitic fluid in the abdominal cavity. However, the clinical results together with the complementary animal experiments provided certain information allowing a better evaluation of the factors playing a part in the passage of the gold. All the patients except one had ascites which,

as mentioned before, was drained off by laparocentesis. It was not possible to decide how completely the abdominal cavity had been evacuated in each case. Ascitic fluid drains away by spontaneous pressure till the flow ceases, after which slight compression may be exerted on the abdominal wall in some cases, and the patient may be directed to change his position so as to make the evacuation as complete as possible. The site of the puncture hole, as well as the possibility that intestine and omentum may fall in around the opening of the trocar are, however, factors difficult to keep under control, and there seems to be little doubt that not inconsiderable amounts of ascitic fluid may remain in the abdominal cavity after drainage. If this is so, then this fluid may contribute towards retarding the permeation in the same way as occurred in the mice injected with Lanschütz ascites. The retardation in the passage of the gold is advantageous to the liver and the remainder of the RES from the viewpoint of the radiation hazards. It is, however, important that the gold should be diluted as little as possible by any remaining ascitic fluid if it is to be absorbed in satisfactory amounts in the peritoneal wall. From this point of view, it is important that the abdominal cavity should be emptied as effectively as possible. On the other hand, it is known that the gelatin-protected gold colloid shows strong affinity for tissue, and there is perhaps some risk that the distribution will be poor if the peritoneum is entirely free from fluid.

As has already been mentioned, 100 to 200 ml of saline is therefore injected after the gold in order to achieve a better distribution. In addition to this, the patient constantly changes his position during the first few hours after the treatment.

No ascites was present in Case VII, but the scintogram nevertheless showed uniformly good distribution of the isotope solution. This indicates that there need not necessarily be any risk that the gold will remain stationary at the site of the injection, even in cases where there is no ascites in the abdominal cavity. The liver uptake in this case was much higher than in the patients with ascites.

This is another observation suggesting that the assumption previously advanced, viz. that carcinosis with persisting ascites is an important factor in causing retardation of peritoneal permeation, is correct. It is accordingly desirable from the standpoint of treatment that the abdominal cavity should be free from fluid. This, however, involves more rapid penetration with an increased uptake of gold in the RES, particularly in the liver, which may become so high that it is no longer negligible. In the case without ascites, the liver uptake was measured as 9.5×10^{-3} % per gram of liver after 24 hours; with a liver weight of 1.7 kg, this corresponds to about 16 per cent of the amount of radioactivity injected.

The number of patients treated in this series is too small to permit

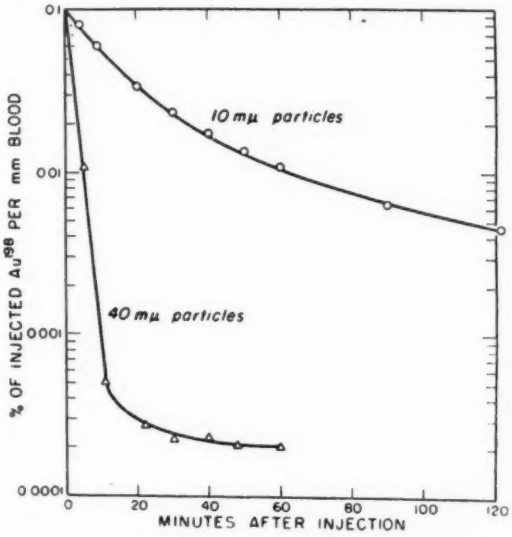

Diagram 1. Curves illustrating the effect of particle size on the rate of disappearance of gold colloids injected intravenously in the dog. Redrawn from ZILVERSMIT et coll. (11).

any conclusions regarding any effect of the PPP, and the results do not indicate any particular effect. It must be emphasized however that the PPP- and control-groups are not strictly comparable as there is an interval of 24 hours between the laparocentesis and gold injection in the PPP group, but in the control group the laparocentesis is followed immediately by the latter. This difference in method — unavoidable for practical reasons in this first series — may have influenced the results. It is known that evacuation of fluid from a hollow viscus, especially if it is rapid, is followed by hyperaemia of the wall of the organ and it is not unlikely that laparocentesis will cause hyperaemia of the peritoneum which may be followed by exudation, a state that is known to counteract absorption (5).

The experimental results presented, as well as the difference in liver uptake between cases with ascites and Case VII without any effusion in the abdominal cavity, seem to justify the conclusion that PPP may be of value in connection with intraperitoneal gold therapy. It is harmless, and if the ascitic fluid can be effectively drained off there is reason to expect that it will retard the diffusion from abdominal cavity to the blood, and hence that the liver uptake will be less, with the result that the local radiation will be increased and the RES more effectively protected from radiation damage.

Viewpoints on the kinetics of diffusion. It has long been known that an intravenously injected colloidal solution is rapidly absorbed by the RES, and more particularly by the liver and spleen, if the particle size is larger than about 20 mμ. ZILVERSMIT et coll. (11) experimented with colloidal Au^{198} in dogs and found that the rate at which the gold disappears from the blood stream after its intravenous injection decreases with decreasing particle size (Diagram 1). This decrease in rate is greatest when the particles are smaller than 15 to 20 mμ.

DOBSON et coll. (3) demonstrated in rabbits that a higher percentage of small particles are encountered in the bone marrow, while large particles are mainly absorbed by the liver and spleen. The gold colloid used in our investigation (with a mean size of about 25 mμ) was obtained from Amersham, England, and has previously been used by KROOK (7) to measure the disappearance of an intravenously injected solution from the blood stream. In his investigation the decrease in the radioactivity in the blood was found to be exponential at first, with a flattening of the curve towards the end. This 'tail' was attributed to the presence of a gold fraction with a particle size so small that it was taken up by the RES either very slowly or not at all (3, 11). The blood activity curves in KROOK's study could be approximated fairly well to two exponential curves referring to a rapidly and a slowly disappearing fraction. From the first exponential curve he obtained a half-life ranging between 3.5 and 6.5 minutes in 'normal' patients.

We have endeavoured to make a quantitative determination of the fraction of an intraperitoneally injected colloidal gold solution that reaches the blood stream and is absorbed by the RES in man.

The following assumptions were made:

1. The uptake of the colloid in the RES was exponential. It ought to be possible to assume this if the greater part of the particles reaching the blood were fairly uniform in size.

2. The liver and spleen were the absorbers. Thus, we excluded the rest of the reticulo-endothelial system (11).

3. The liver and spleen took up the gold homogeneously at the same rate *i. e.* the activity per gram of tissue was assumed to be the same at one and the same moment (1, 8).

4. The combined weight of liver and spleen was 1.8 kg, and the blood volume 5 000 ml.

If U_t is the liver and spleen uptake, B(t) the blood concentration at the time, t, and λ the rate constant, we obtain

$$\frac{dU}{dt} = \lambda\, B(t) \quad \text{or} \quad U_t = \lambda \int_0^t B(t)dt$$

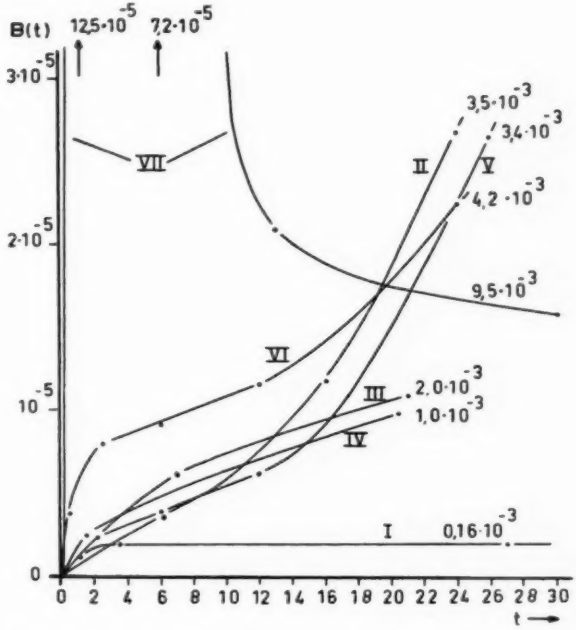

Diagram 2. Blood activity per ml of blood as a function of the time in the 7 patients in Table 4. B(t) values for Case VII at 2 and 6 hours denoted by arrows. Roman numerals indicate the patients in Table 4 and arabic numerals the specific liver activity at the time when the last blood sample was taken, as a percentage of the total amount of Au^{198}.

U_t and B(t) could be determined by liver punctures and blood tests. $\int_0^t B(t)dt$ was then determined from Diagram 2, and the half-life $T_{\frac{1}{2}}$ was obtained from

$$T_{\frac{1}{2}} = \frac{\ln 2}{U_t} \int_0^t B(t)dt$$

It should be noted that $T_{\frac{1}{2}}$ is not a true half-life, since only the uptake in the liver and spleen has been used in the calculation. About 10 % of the totally absorbed Au is taken up by organs other than the liver and spleen. However, if the aforementioned assumptions are adequate — and earlier researches have shown that they are (1, 8, 10, 11) (i. e. that the distribution of the gold in the liver and spleen on the one hand and in the other parts of the RES on the other is constant) — then the quantity $T_{\frac{1}{2}}$ should be capable of giving a good idea of the uptake rate.

Diagram 3 shows $T_{\frac{1}{2}}$ as a function of the liver activity as a percentage per gram of tissue (liver and spleen) of the total amount of Au^{198} injected. For liver activities of be-

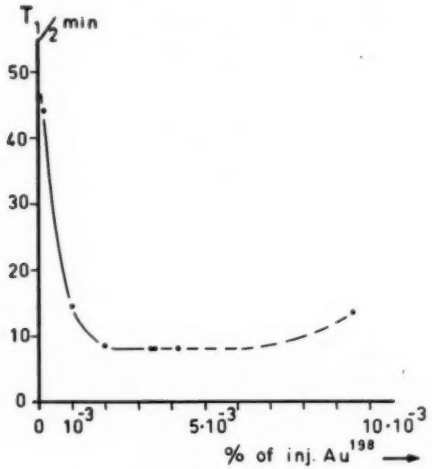

Diagram 3. $T_{\frac{1}{2}}$ as a function of the spec. liver activity expressed as a precentage of the total amount of Au^{198} administered. $T_{\frac{1}{2}}$ is the time required for one-half of a certain amount of Au^{198} in the blood to be absorbed by the liver and spleen.

tween $2 \cdot 10^{-3}$ and $4 \cdot 10^{-3}$ % per gram of liver the $T_{\frac{1}{2}}$ was found to be constant, around 8 min. The fact that $T_{\frac{1}{2}}$ is constant in this interval suggests that the fraction which reaches the blood stream is homogeneous as regards the size distribution of the particles, and that the assumptions made above are correct in this interval. Owing to a coincidence, the values in our investigation are more uniform than might be expected considering the many approximations. A variation of t 10 % for $T_{\frac{1}{2}}$ may probably be expected.

The $T_{\frac{1}{2}}$ values obtained in our investigation are higher than those of KROOK, which shows that the mean size of the particles in the blood was much smaller than the mean size in the original colloid injected intraperitoneally. A dialysis test revealed that 73 and 65 per cent, respectively, of the blood activity in Cases VI and VII (Table 4) was diffused out during 48 hours, whereas 23 and 25 per cent, respectively, of the similarly treated original solution diffused during the same time. Accordingly, in the patients examined, the peritoneal membrane and the lymph nodes in the subperitoneal connective tissue absorbed fairly effectively particles 25 mμ in size during the first 24 hours after the injection, in other words, the greater part of the colloid administered.

With liver concentrations of less than $2 \cdot 10^{-3}$ % per gram of liver, the mean particle size in the blood was evidently so small (the filtering capacity of the peritoneal wall was extremely high in these patients) that the uptake rate in the liver had decreased, and the $T_{\frac{1}{2}}$ value was consequently high.

In Cases I to VI (Table 4) the amount of Au^{198} that reached the blood ranged from 50 to 1 000 γ. VETTER et coll. (10) demonstrated that amounts of gold (of the type we have used) of up to 500 γ in the blood do not affect the uptake rate; an effect was noted, on the other hand, when the amount of colloid was 1.5 mg, as the phagocytizing capacity of the liver had obviously been exceeded. The $T_{\frac{1}{2}}$ value was for this reason larger in Case

Table 4

(se material. Two other patients were given preliminary PPP treatment without liver 1 nctates being taken. The blood activities of these did not differ significantly, however, from the activities normally found in patients with ascites not given preliminary treatment

Case	PPP 1 g	% gold per g of liver of total amount injected
I	—	$0.16 \cdot 10^{-3}$
II	—	$3.5 \cdot 10^{-3}$
III	—	$2.0 \cdot 10^{-3}$
IV	—	$1.0 \cdot 10^{-3}$
V	+	$3.4 \cdot 10^{-3}$
VI	+	$4.2 \cdot 10^{-3}$
VII	—	$9.5 \cdot 10^{-3}$ *

* Only case without ascites.

VII than in the others. The same feature was observed in a few other cases not included here, in which it had been necessary to administer larger amounts of gold than usual because of the physical decay. In all probability, the phagocytizing capacity of the liver does not depend primarily on the amount of gold, but rather on the number of particles, since solutions with fairly large particles and of much higher weight have been effectively absorbed by the liver without its capacity apparently being exceeded (3, 10).

We assumed in the beginning that the specific radioactivity of the liver should be the same as the specific spleen activity at one and the same time. An experiment carried

Table 5

Liver and spleen activity in mice. Activity of the organs measured 3 hours after intraperitoneal injection of gold

Animal	Organ	Counts/min	Spleen activity/ Liver activity
1	Liver	48 105	
	Spleen	8 038	0.17
2	Liver	80 110	
	Spleen	15 532	0.19
3	Liver	87 610	
	Spleen	15 532	0.18
4	Liver	41 975	
	Spleen	7 980	0.19
5	Liver	36 930	
	Spleen	7 794	0.21
6	Liver	62 400	
	Spleen	16 166	0.26
7	Liver	76 295	
	Spleen	7 200	0.10

out on mice showed that this need not necessarily be the case (Table 5). As in the case of man, the weight of the spleen in mice is about 10 per cent of the liver weight. The amount of gold injected in this experiment probably greatly exceeded the phagocytizing capacity of mouse liver; this, together with other physiologic differences, may conceivably explain the relatively high spleen uptake in the mice.

Dose calculation

The β dose in liver and spleen (9) is obtained from the formula

$$D_\beta = 744\,\varrho \text{ rad/hr}$$

where ϱ is the activity in mC per gram of tissue. As the liver activity increases continuously the total dose will undoubtedly be larger than when it is calculated on the basis of the 24-hour uptake. If the 24-hour uptake is taken as the basis, however, we obtain

$$D_\beta = \frac{744 \cdot 65\varrho}{\ln 2} \text{ rad}$$

When no appreciable ascites is present, as in Case VII with $9.5 \cdot 10^{-3}$ % per gram of liver of the total amount of Au^{198} injected, we obtain a dose of 660 rad if the patient, as in this instance, has been given 100 mC and, as the γ dose probably constitutes at least 10 per cent of the β dose, the total will be

$$D_{\beta+\gamma} = 730 \text{ rad}$$

This must be regarded as a fairly large dose, and if possible it should be avoided. The afore-mentioned preliminary PPP treatment is an aid in this respect.

SUMMARY

The permeability of the peritoneal membrane to radioactive colloidal gold has been investigated. Treatment with polyphloretin phosphate (PPP) prior to palliative gold therapy in patients with carcinosis and ascites is discussed. Although PPP had no appreciable retarding effect on the absorption of Au^{198} from the abdominal cavity in cases with ascites, the experimental results indicate that the injection of PPP prior to treatment with Au^{198} should prove advantageous in cases without ascites or where the abdominal cavity has been effectively drained.

ZUSAMMENFASSUNG

Die Durchlässigkeit der Peritonealmembrane für kolloidales Gold ist untersucht worden. Die Behandlung mit Polyphloretinphosphat (PPP) vor der palliativen Goldbehandlung bei Patienten mit Karzinomatosis und Ascites wird diskutiert. Obwohl PPP bei Ascitesfällen keine merkbare verzögernde Wirkung auf die Absorption von Radiogold aus der Bauchhöhle hatte, deuten die experimentellen Ergebnisse doch an, dass die Injektion von PPP vor der Behandlung mit Radiogold, in Fällen ohne Ascites oder wenn die Bauchhöhle effektiv drainiert worden ist, sich als vorteilhaft erweisen dürfte.

RÉSUMÉ

Les auteurs ont étudié la perméabilité de la séreuse péritonéale à l'or radioactif c lloïdal. Ils examinent l'effet de l'administration de phosphate de polyphlorétine (PPP) a ant le traitement palliatif par l'or chez les malades atteints de carcinose avec ascite. E en que le PPP n'ait pas eu d'effet retardateur appréciable sur l'absorption de Au^{198} c ntenu dans la cavité abdominale dans les cas avec ascite, les résultats expérimentaux i liquent que l'injection de PPP avant le traitement par Au^{198} devrait être utile dans le cas sans ascite ou dans les cas où la cavité abdominale a été convenablement é acuée.

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BOOK REVIEWS

L'Angiografia Nella Diagnostica Urologica (Angiography in urologic diagnosis). Della C. Malchiodi, G. Reggiani, E. P. Berti-Riboli e G. B. Cerruti. 130 pages, 69 illustrations. Edizioni Minerva Medica, Torino 1957. Price Lit. 1 500.

Abdominal aortography according to the original technique of Dos Santos was performed in about 500 cases in order to investigate the kidneys and the pararenal glands. The technique is described in detail. Contrast media are discussed and the contra-indications and dangers are analysed. The normal abdominal and pelvic angiographic anatomy are described with special reference to the normal angiographic appearance of the kidneys. The authors then deal with the special renal and pararenal pathology, including anomalies, renal cysts, polycystic kidney, traumatic changes, embolism and thrombosis of the renal arteries, as well as various types of aneurysms, hydronephrosis, tuberculosis of the kidneys and renal and pararenal neoplasms. The last chapter of the book deals with neoplasms of the urinary bladder and the prostate gland; these organs were investigated by means of retrograde and forced injection of contrast medium into the femoral artery bilaterally, according to the technique originally suggested by Castellanos and Pereira, which makes retrograde filling of the terminal branches of the hypogastric arteries possible.

An extensive bibliography is appended.

Francesco S. Tolone

Arteriografia addominale e delle estremità (Abdominal and peripheral arteriography). Del Antonio Rabaiotti, Lucio Rossi e Giorgio Prevedi. 466 pages, 202 illustrations. Edizioni Minerva Medica, Torino 1957. Price Lit. 7 500.

The authors have made use of a material collected at the University Clinics of Parma over a period of about 7 years and consisting of about 1 000 cases of abdominal and peripheral arteriography.

The various techniques are first dealt with in detail, the indications, limitations, and potential dangers then being considered. The normal anatomy is next described. After some general viewpoints on the vascular circulation another chapter deals with the pathology of the vessels themselves, together with a consideration of the so-called osteovascular dysplasias. Next follows a chapter on vascular changes in diseases of various abdominal organs including the urinary bladder and prostate. Arteriography in obstetrics and gynaecology is also discussed. A short chapter deals with retroperitoneal tumours and another with arteriography in diseases of the bones and joints and of the soft tissues. In the last sections of the book the investigation of benign and malignant conditions of the thyroid gland is described.

The book really consists of a survey and embodies nothing particularly new in the field. An extensive list of references is included.

Francesco S. Tolone

ROENTGENOLOGY OF THE CHEST. Edit. Coleman B. Rabin. 506 pages, 327 illustrations. Charles C. Thomas, Springfield, Ill. $ 19.50.

This book is the product of a number of authors who all represent specialist knowledge in particular branches of the wide field of thoracic roentgenology. The different chapters vary in quality but it may be said, as a general observation, that the chapters dealing with general principles and with conventional roentgen examinations are good and contain valuable information. This applies only to the text, however, since the reproductions of roentgenograms leave much to be desired. It is in fact surprising that radiologic publications in the U.S.A. so often contain illustrations of inferior quality, as compared to the European standard.

If thus the conventional examination is treated well, and by some authors in an excellent manner, the descriptions of specific examination methods are less good. The chapter on 'Cyanotic types of congenital malformations of the heart' might have filled a need some fifteen years ago, but even at that time SUSSMAN, GRISHAM and STEINBERG published much better work in the same field. A comparison with the publications of CASTELLANOS and his collaborators on angiocardiography will also make clear the unsatisfactory nature of this chapter. The term 'selective angiocardiography' is used in a manner not encountered before by the reviewer. That specific procedure in selective angiocardiography, which consists of injection of contrast medium through a catheter into the heart cavities or the great vessels, is not mentioned at all. This must be regarded as a serious shortcoming in a textbook which was published as late as 1958. DOTTER, who has written the chapter on 'Acyanotic forms of congenital heart disease', takes a negative attitude towards selective angiocardiography and exaggerates its risk. As far as can be judged, however, he appears to have had little first-hand knowledge of the method. His chapter, which is without illustrations, is in other respects well written and offers a good description of the acyanotic forms of congenital disease as seen in conventional roentgenograms.

In a separate chapter, the use of metaphors, which in our days seems quite out of place in radiologic language, is seriously discussed. Among the worst of figurative expressions of this kind is 'vanishing tumor'. There is, as is well known, no question of tumor in such instances but of fluid encapsulated in an interlobar fissure. This is also made clear by the author but it is to be regretted that he takes no firm stand against the use of such objectionable misnomers. The same may be said about 'butterfly shadow' which covers no unitary pathologic conception. The typical appearance of the thymus is called the 'sail sign', and, instead of being condemned and discarded from the radiological terminology, this expression is discussed in all seriousness. The author speaks of the 'talk plaque', by which he means 'plaque-like deposits of calcium in the pleura, especially in the diaphragmatic region'. This roentgenographic sign is considered to be characteristic of talc pneumoconiosis, which is not correct, however, since it occurs consistently also in asbestosis. The author who wrote about silicolis and silicotuberculosis does not appear to have been familiar with the pathogenetic difference between silicosis and asbestosis.

In the chapter on 'Diseases of the chest wall' GARLAND & SISSON write that there are many reasons why the radiologist should examine the patient by simple inspection or palpation prior to the roentgenographic examination: ... "if such inspection were a routine part of medical X-ray examination ... there is no question that some diseases would be detected at an earlier stage than they are at present". This is read with some surprise by a Scandinavian radiologist who considers that individual contact between the radiologist and the patient is always necessary and should never be neglected.

The book thus contains much to invite both criticism and discussion but it may nevertheless be recommended as being on the whole valuable.

Gunnar Jönsson

AMÉLIORATION ET REPRODUCTION DES RADIOGRAPHIES PAR MODULATION ÉLECTRONIQUE (le logetron). Par A. Jutras et H. Fischgold. 121 pages, 28 illustrations. Masson et Cie, Paris 1958.

An original film may be copied by means of the 'Logetron' apparatus in such a way that every part is reproduced in proportion to its density. The whole duplicate is thus harmonised and the various details equally presented.

The light from a cathode ray tube is projected through the negative and the copy film which are held together in contact. The light then reaches a photocell from which the light output of the cathode tube is controlled. When a dense area of the negative is scanned a diminished signal produces a feedback to increase the intensity and vice versa if a transparent area is encountered.

The authors have examined the value of the method for improvement of the original negative in various roentgen-diagnostic techniques. The method has proved to be of the greatest value for demonstrating soft tissue structure and certain views of the skeleton have also been considerably improved. The reviewer does not like the 'logetronized' film of the chest for he finds disturbing the way in which the ribs are reproduced.

The book contains a detailed description of the principles of the method, the technique, and the results.

Folke Knutsson

LE MANIFESTAZIONI INTESTINALI DELLA MALLATIA DI NICHOLAS-FAVRE (Intestinal manifestations of Nicholas-Favre's disease). Del Serse Zanetti con la collaborazione del Dr Leonardo Di Domizio. 149 pages, 156 illustrations. Cappelli Editore, Bologna, 1957. Price Lit. 4,000.

Forty-four cases of Nicholas-Favre's disease (lympho-granuloma venereum) with intestinal manifestations were encountered in a material of over 90 000 roentgen examinations of the gastro-intestinal tract. The book contains reports of 34 of these cases, 14 of which occurred in males and 30 in females, the ages varying between 27 and 69 years; in all cases the disease seemed to be related to sexual intercourse. Typical segmental lesions of the recto-sigmoid region of the bowel were observed in all the cases; the whole sigmoid colon was involved in 10 cases and the descending colon only in 2. Sinuses or fistulae (recto-vaginal or recto-vesical fistulae) were common complications. The roentgenologic aspects of the disease, its etiology and pathogenesis, and the diagnostic procedures, as well as the sequelae and treatment are all dealt with in detail. Numerous publications on the subject are quoted at the end of the book.

Francesco S. Tolone